A STUDY

OF THE

HISTORY

AND OF THE

ART OF BREWING;

Being a Descriptive and Historical Essay on the

ARTS OF BREWING AND MALTING,

And comprising a Sketch of

BREWING LEGISLATION AND TAXATION,

With the appropriate Statistics annexed.

BY

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NOTICE.

Two years have elapsed since I published my work, *A Study of Original Gravity.* A most generous reception has been given to that work, and it is now in the hands of almost every brewer of importance in the United Kingdom. I have thus been encouraged to publish the present work, though aware of the many excellent works which travel over some of the same ground. I have, however, aimed more at a popular and descriptive work, embracing all aspects of the brewing art and trade, than at a technical and scientific treatise. The portion at the beginning of this work which treats on the Historic, the Progressive, and, it might also be said, on the Metamorphic phases of the subject, as well as that larger portion at the end, which treats on the subjects of Legislation, Taxation, Invention and Discoveries, Statistics, Wort and Beer Constituents, Adulteration, Comparative Costs and Values of Grain and Sugar Materials, will, I confidently hope, be found specially interesting.

To brewers, brewing pupils and students, and to all interested in brewing and malting questions, I therefore confidently recommend this work.

J. A. NETTLETON.

GRIMSTON,

NEAR KING'S LYNN,

November, 1883.

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A STUDY

OF THE

HISTORY AND OF THE ART OF BREWING.

NOTE.—As an aid to the thorough study of so large a subject, it has been divided and subdivided into Headings, numbered progressively.

1.—HISTORICAL.

The Art of Brewing has been practised for thousands of years. It is known, on the authority of Herodotus, that the Egyptians drank fermented barley-wine or beer. The site of a very ancient brewery in Egypt is supposed to be preserved at the spot where a modern one exists. The old nations in the South of Europe are reported to have drunk similar beverages, whilst the authority of Tacitus and of Pliny have been respectively invoked to show that beer was made in Germany, and that the Westerns generally got drunk upon it. Our own ancestors, both Saxon and Danish, are charged with like offences by Hume and by many other historians. History and literature alike show that for centuries beer and other fermented liquors have been our national beverages. Indeed, in a great many countries, both ancient and modern, one kind or another of fermented liquor has been known, which has been extracted or prepared from the vine or from some other fruit, or from roots or cereals. Recently it seems to have become generally known that, in Zululand, "huyembo" beer is made from millet and mealies, and in Japan "saké" is made from rice. In our own country, as well as in others, wine and ardent spirits on the one hand, and tea, coffee, and a host of other drinks on the other, have for a long time been formidable rivals to the old staple beverage, beer. Amongst certain classes, or in certain parts of the kingdom, one or the other of these rivals predominates entirely over beer, whilst almost everywhere, beer in two meals out of the three has been altogether supplanted. Yet brewing is now as much, or more than ever, one of our largest national industries, and beer drinking is still one of our widest and most general customs.

2.—GRADUAL DEVELOPMENT OF THE BREWING INDUSTRY.

During the last hundred years the development of the brewing industry has been wonderful. Improvements have been introduced which in all matters of detail have completely metamorphosed the brewing process. In some other respects, however, little or no change has occurred; thus, in spite of the legislation of 1847 and of 1880, and of less important years, malted-barley and hops still continue to be the chief brewing materials. However legislation may have affected brewers, it is clear, nevertheless, that both the art and the trade of brewing have always steadily, nay, rapidly, been progressing. As an art, brewing, pressing science into its service, has kept up to or even gone before the times, whilst as a trade it has grown to gigantic proportions, and has amassed princely fortunes. In numerical strength (as will be shown further on) brewers have fluctuated up and down as taxation and revenue restrictions, imposed or abolished, appeared to favour or retard their freedom, but competition (as the country has been gradually opened up) between brewer and brewer, between large capitalists and small capitalists, has for the last forty years been the main cause of the falling off in numbers. In aggregate wealth, however, the same period of time has been on the whole very bountiful to the trade.

3.—INTRODUCTION TO MODERN BREWING AND TO MODERN BREWING MATERIALS.

The brewing process as practised in thousands of our breweries, though broadly and generally the same, necessarily admits of great variety in detail. The kinds and the qualities of the materials used differ; the treatment in many important details differs; there is great difference in the skill and knowledge brought to bear upon each step of the process; the water differs in quality, the plant differs in proportions and in make, and the final products differ—many varieties of ales, porters and stouts being manufactured. Distinctions as broad as those existing between wines obtain in beer, and are shown in the varieties of alcoholic strength, acidity, age, fulness of flavour, purity, colour, &c. A description of the brewing process dwelling upon each detail as it is most generally practised, and pointing out where the principal variations occur, will perhaps afford the best means of understanding the whole subject.

Barley-malt and hops it has been stated have always been the chief materials used in brewing; for many, many years they were the only materials allowed to be used, and they yet preponderate considerably over all other materials. Many of our largest brewers justly pride themselves upon their faithful adherence to these staple materials, and upon their selecting only the best qualities of these. Barley-malt has, perhaps, always held supremacy over other kinds of malt, so that there must have been strong practical reasons for the preference of barley over other British grains. Among other reasons for this, there are the comparative ease and celerity with which it can be malted, its regu-

larity under this treatment, and the superior flavour which it imparts to beer. It is a hardy crop grown in all parts of the kingdom; the amount of land under its cultivation fluctuates so much from year to year (according to official reports) that beyond saying both in Scotland and Ireland it is a far smaller crop than oats, and that in England there is often less barley acreage than there is wheat acreage, it would be unsafe to make more exact comparisons. Comparing the prices of raw grain, barley is cheaper than wheat but dearer than oats; it contains less, though not considerably less, starch than the other cereals, but what comparisons it would bear if all the three chief ones (wheat, barley and oats) were malted are hardly well known. In point of cheapness too maize has the advantage over barley, and it has had this for some time; still, neither this nor any of the other cereals have been used to anything like the same extent that barley has for malting, and consequently until 1880 for brewing. Legislation during Her Majesty's reign has gradually allowed the introduction, first of sugar, then of hop substitutes, next of other sugars and syrups, and finally of any kind of raw grain or of wort-producing material. Malted barley has now to contend against a large number of rivals, and as it has done with regard to its older rival sugar, so it will do with regard to its later ones; it will to a certain extent give place, but it may perhaps be safely said that these subordinate materials will never exactly speaking be substitutes for, but rather adjuncts to the old staple. How all these secondary materials affect the brewing process must be fully considered, but priority must be claimed for brewing with malted barley alone.

4.—MALTING.

(A) *Principles of Malting.*

Malting is so intimately connected with brewing that a good understanding of it is essential for the brewer's purpose. It is an art which is as venerable as that of brewing itself. Apparently a very simple process its exact character has been but rudely understood, and even now the scientific knowledge of it is bare and vague. Malting of today probably greatly resembles the process as it was followed in its most primitive times. It is the habit of sciolists in brewing subjects to sneer at the maltster for pursuing his calling in all its original simplicity. Excuses could be made for him so long as he was supposed to labour under excise tyranny, but since his emancipation in 1880, he has been continually called upon to revolutionize his time-honoured but, it is alleged, antiquated process. Nevertheless, the maltster has shown himself wonderfully callous to this clamour for change, proceeding as it does from non-practical journalists. The fact is the old style of malting works well, although improvements can be and are introduced; perhaps their adoption is slower than in other trades, because their need is less.

Whatever disputes there may be concerning the chief objects of malting, the secondary results obtained are:—the expulsion of oily matter from or the modification of it in the grain; the overcoming of the natural cohesiveness of the grain; the acquirement of brittleness and friableness; and the imparting of an agreeable flavour in lieu of the raw unpleasant one of the grain—this flavour being effected partly by the furnace heat, and partly by the absorption of furnace products

Old authorities agree in saying that the chief object of malting is to convert the starch of the grain into sugar. A recent writer on brewing insists that this object is not effected. Technically he is correct, though practically the old authorities are not far wrong. The production of sugar is an indirect result of the malting process rather than a direct one; comparatively little sugar is formed during the actual process, though immediately the malted grain is mashed it becomes apparent that much sugar has been created. There was, however, great reason for supposing that very much more sugar existed in malt than in its original barley (if indeed any existed in the raw material). The ta·te of malt is decidedly sweet, arguing sugar; but it is contended by recent investigators that this sweet taste, though not exactly created, is still greatly enhanced by the invertive power that saliva possesses, so that during the short interval that the malt grist remains on the tongue, a quantity of starch or of dextrin is converted into sugar; though independently of this a very small percentage of sugar (far less than the old authorities would have contended for as present in malt) would be sufficient to impart the sweet taste. Again, the old authorities when analyzing malt for its sugar estimation, usually treated it with water in order to extract the sugar, but they were unaware that whilst doing this the circumstances were more or less favourable for the partial or complete conversion of the starchy matter into dextrin and sugar; if indeed the temperature of the extract were favourable and the time sufficient, all the starch would be thus converted. Hence more or less sugar was always found in an aqueous extract of malt. If slightly acidulated water were used to hasten the extracting process, the creation of sugar was far more rapid and complete. When, however, raw barley was treated with water for the same purpose, little or no sugar was found, unless acidulated water were employed. Again, any brewer mashing malt would be sure to find a kind of sugar in the wort, its sweet taste alone would persuade him that he had obtained sugar from the malt. It is a disputed point even yet how much sugar exists in a given sample of malt, for even with the greatest care to avoid the production of sugar during the necessary analytical treatment, more or less is sure to be formed. Whether or not barley contains any sugar is also a disputed point, for much the same difficulty exists in performing the analysis. The probability is that a small quantity (perhaps 1 per cent. more or less) of sugar exists in barley, and that this sugar closely resembles cane sugar. In malt, too, there is actually present a small quantity of sugar, probably more than exists in barley.

Besides this, and the well-known physical differences existing between barley and malt (such as taste, smell, colour, lightness, brittleness, rupture of skin, growth of plumule, &c.) the following facts have been clearly established, and serve to show what changes are effected by malting. Barley and malted-barley both contain cellulose and from two to three per cent. of mineral matter, the latter chiefly consisting of alkaline and alkaline-earthy phosphates, sulphates and chlorides, which in due time are imparted to the beer. For the present comparison no further notice need be taken of these constituents. Barley contains usually 10 per cent. or more of moisture, a small quantity of oily matter, 50 to 60 per cent. of starch, and 11 per cent. or more of albuminous matter. Malted-barley is usually drier than barley, has less oily matter and less starch, and much about the same amount,

though slightly less, of albuminous matter. Some of this however has by the kiln-drying been rendered less soluble, some has been burnt, but probably all of it has been affected by the germination process. Besides these constituents, malt contains, according to the temperature it has experienced on the kiln, certain ill-defined bodies, called usually empyreumatic bodies or products of torrefaction, and these seem to consist of partially or wholly caramelized starchy matter, and of burnt albuminous matter, burnt husk, &c.; these give the colouring to malt infusions. But the essential difference between barley and barley malt lies deeper than any of the minor differences alluded to, this important change evinces itself when a solution of malt extract is made and compared with a solution of barley extract. The latter even under favourable circumstance is turbid and only slightly sweet, the former is clear and distinctly sweet. The explanation readily given is that the barley solution contains much starch, whilst the malt solution contains very little, perhaps not even a trace, but contains instead much sugar called maltose, and also more or less dextrin. Albuminous matter is present in each solution and in much the same proportions. It appears then that the malting has effected a change which shows itself thus prominently when a solution of the malt extract is made, shows itself in fact immediately the solution is made. This change is all-important to the brewer. Can the cause of this difference in the malt and barley solutions be traced any further? To do this a little study must be given to the albuminous matter present in both solutions. The albuminous matter though in amount much the same in a grain of malt as in its primitive barley grain has yet a very different character. Of the total amount of albuminous matter present in either malt or barley a certain part is soluble in water, and of this soluble portion the greater part, if indeed not the whole, is coagulated by heat as the water's temperature is raised to the boiling point, and what portion is not actually precipitated is partly broken up. Of this soluble and eventually coagulable albuminous matter there is perhaps a little more in a barley solution than in a malt one, because there is more in barley than in malt, but as compared with those present in the malt solution the barley albuminoids are very feeble in their action upon starch, their power being only one fiftieth or one hundredth that exercised by the same quantity of malt albuminoids, they convert starch to sugar very, very slowly, and moreover this feeble power is very soon destroyed as the temperature of the solution rises and these albuminoids are precipitated. Patient investigation by men eminent in their profession has shown that the differences observed between a barley wort and a malt wort can be thus traced to the action of the soluble albuminoids. By the process of malting, especially that part of it which consists in the grain's germination, certain changes take place in the character of the soluble and coagulable albuminoids, they acquire a certain potential energy, and this energy developes itself in the direction of converting starch to dextrin and maltose immediately sufficient water at a suitable temperature permits of its free action. The growth of the plumule is one of the most evident changes which accompany the acquirement of this power, and it is in a broad sense an indication of the amount of this acquired power. This power may be termed the diastatic power. The albuminous matter so affected was formerly called diastase, and is often called so now, though there is strong

reason for supposing that almost the whole, if not the whole, of the soluble albuminous matter of barley could, through the germination process, acquire the diastatic power and so be called diastase. In discussing the mashing process it will appear how this power can be governed, how it can be fully or only partially utilised at pleasure, and how it can when desirable be annihilated, the proper use of this power being a point of greatest importance in mashing. Here it suffices to show that the really essential result of malting is, popularly expressed, the creation of diastase; more exactly it is the acquirement by the soluble albuminoids of a power capable under proper conditions of converting starch to dextrin and maltose. Messrs. Heron and Brown do not hesitate to believe that diastase as a distinct body has no existence, but rather, that the diastatic power is only a function of the soluble and coagulable albuminous matter of grain, a power acquired during germination by the glutinous matter of grain. To go deeper and to enquire why this power once created should exert itself in its particular way is no easy task, requires special study, and is a subject for future investigation. Diastase has often been said to have been isolated from malt, and very varying results as to its amount have been obtained; it is probable that these discrepancies can be explained by assuming the diastatic function of the whole soluble albuminous matter, and showing that more or less of this substance has been extracted according to the variations of the experiment.

(B) *Practical Details of the Malting Process.*

These are so well known that only a brief allusion to them is necessary. Much has been written on the comparative advantages of hard and soft water in steeping. Undoubtedly the hardness or the softness of the water has its effect, especially if great extremes of these prevail. But beyond the purely scientific interest attaching to the infinitesimal differences ensuing from the use of hard or soft water, which differences can only be illustrated after a most careful analysis, no attention need be claimed for this subject. Here malting must be considered as it is carried on upon its usual scale in a malt-house, not as it might be typified by miniature maltings in a laboratory. The differences in hardness likely to be met with in steeping water must not be exaggerated. A difference of ten or twenty degrees of hardness, that is of ten or twenty grains of carbonate or sulphate of alkaline earths in a gallon, can under the usual malting system have but little effect. The water is used at a cold or at least a very moderate temperature, so that complex chemical action must be sluggish, so too must be the simpler one of the solution of either mineral or organic matter from the grain, whilst the difference caused to the barley by the presence of a few grains of alkaline or alkaline earthy salts in the water, which water be it borne in mind merely soaks and finally drains through a mass of barley, must be very little. The salts giving temporary hardness theoretically exercise the power of neutralizing organic acids set free in the steep water, whether they do so in practice is not so sure. If, however, the water and grain were thoroughly stirred up together, or were heated or boiled together, far greater differences would be created. The hard or soft character of the water has especially been studied in reference to its action upon the grain's albuminous matter, for when boiled or heated with hard water more albuminous matter is deposited;

this point should of course be studied in the mash-tun, but in the steeping cistern, and with cold water to try and accelerate the desired end, is an act of supererogation. Of far more importance than the water's hardness is its character for purity as regards organic matter, and this should be studied in conjunction with the proper and periodical draining of the grain, especially in warm or mild weather, so as to prevent the growth of putrid and fetid organisms in the water, and the consequent decomposition of the grain's albuminous matter. Another important matter is the choice as to the best barley for malting. Then there is the treatment during all the details of wetting, germination and drying. The depth of the grain on the germinating floor and the consequent regulation of heat must be studied so as to ensure steady but not rapid growth, so too must the carrying on of germination to the proper extent, the careful watching of the growth of the plumule affording a good guide in this respect. If the grain be too little grown the changes in the albuminous matter are insufficiently marked, the diastatic power is not fully developed, hence the growth of the plumule is a good practical test of possible diastatic power. Then there is the withering of the grain and next its drying. The temperature at which the grain is dried has an important effect upon the quality of the malt. The drying should proceed regularly, both as to increase of temperature and to the equal distribution of heat all over the grain area. An ascending series of temperatures is coincident with a deepening in the colour of the malt, this colour of course greatly governs that of the beer. The progression in colour is the merely physical appearance of other accompanying physical and chemical changes, for as the colour deepens so the grain becomes lighter and lighter in weight, more and more brittle and dry, whilst oily, aqueous, and other volatile matters are gradually driven off. The phases of colour generally recognised are pale, amber, brown and black, though malt of the latter description is usually finished off at high temperatures in revolving cylinders placed above or in furnaces. Pale malt is dried at a temperature of about 140° F., amber at about 170° F., and brown at about 180° F. Up to a certain point the amount of dextrin formed seems to increase with the temperature of the drying; a high heat is probably favourable to dextrin formation, but the diastatic power is gradually nullified by the same. At 300° F. starch is converted to dextrin, it is probable that bodies more or less resembling this are formed on the kiln at much lower temperature, but it is difficult to explain why. As to the body called caramel, formed at high temperatures from sugar, no distinct composition can be ascribed to it, it probably consists of several dehydrated carbohydrates. Caramel-like bodies are lighter and drier than starch, and they possess strong colouring properties. The bodies classed generally as products of torrefaction increase as the heat is raised. In making black malt much of the starchy matter is caramelised, and some of it as well as some of the albuminous matter is carbonised, so that extract is sacrificed at the expense of the colouring matter produced. The materials used in the furnace and their volatile products absorbed by the malt influence the finished article.

The newly-finished and screened malt shows an average loss of weight of 18 to 20 per cent. of the original barley, Most of this is through the expulsion of moisture, barley containing perhaps 10 per cent. more of this than dry malt, whilst about 4 per cent. of the barley

is said to be lost with the rootlets, the remaining loss being accounted for by the solution of organic and mineral matter by the steep water, by the formation and escape of carbonic acid, and by other minor changes. In bulk, malt occupies six to eight per cent. more than its original barley bulk. A bushel measure of pale malt weighs from 40 to 41 lbs., of black, brown or crystalline only 30 to 34 lbs.

5.—SITUATION, WATER SUPPLY, AND GENERAL CONSTRUCTION OF A BREWERY.

Besides its importance from a trading point of view, the site of a brewery has much to do with the process of manufacture and with the character of the product. For instance, there is the character of the water supply, the purity or otherwise of the atmosphere, the exposure or non-exposure of many parts of the plant or of the stores to solar light and heat, to winds, to dampness, steam, &c., all these things being of great importance for other than merely commercial considerations. The water must be studied as to its purity, origin, immediate source, its quantity, constancy of supply, temperature, and its hardness or softness. The latter alternative quality may almost entirely govern the kind of beer produced, whether it should be pale ale, or whether the water's quality is better suited for darker ales or for stouts and porters. Some breweries, favourably situated, have a constant and independent supply of good and cold water from springs or deep wells, some times the water is conducted for considerable distances through tunnels from its source. Some wells will yield hard water at one depth and softer water at another, a special knowledge being required in selecting the best sites for well-making. Sometimes a brewery can obtain in addition to its own peculiar supply another one from the local authorities' supply, using the latter water only for cooling, cleansing, and other minor purposes. Less fortunate breweries are dependent entirely upon the local public supply. The use of water which chemical analysis and practical observation alike pronounce to be deleterious should be avoided. If the supply is not of the quality desired, various expedients are resorted to for purifying and for improving it. Some brewers cause the water to pass through large charcoal filters, or through gravel and sand, or through cinders—these devices more or less answer their purpose. Beyond the expense, and provided there is sufficient space at disposal, the proper filtration of the mashing water, either direct, or, better still, after having been carefully drawn off from subsidence tanks, presents little difficulty that cannot be overcome with ingenuity. The filtering material, whatever it is, must be periodically cleaned or renewed. To improve organically impure water chloride of lime has been suggested. In order to produce water resembling the celebrated Burton water various devices are adopted; the commonest and simplest is to cause the water to pass through or over several inches of gypsum. The system usually followed of placing this substance in lumps or blocks at the bottom of a cistern must give unsatisfactory results. Suggestions have been made that instead of this the finely-powdered gypsum should be added to the water, either by direct mixing, or better, by first stirring it up in a pail of water and then pouring the mixture into the tanks. This mode

would give better and more constant results, and the requisite number of grains per gallon could be easily regulated. Besides the use of gypsum for giving permanent hardness more complex mixtures are employed, which when used in proper proportions can be easily shown to impart to water the necessary number of grains per gallon of alkaline and alkaline earthy salts, so that at least a careful chemical analysis would make the water to resemble Burton water. But though these practices carefully carried out will undoubtedly improve a water, they can never make it approach in real quality a naturally hard water, such prepared waters must at the best be but poor imitations of their model. The real essence is lacking—the maturity and the natural aeration and filtration—for it is too much to expect that a few minutes' or hours' treatment with salts in the proper resulting proportions will make a water equal in quality to one which has undergone a constant treatment on a large scale for weeks and months. Such a prepared water only resembles the natural water as doctored gooseberry wine resembles genuine champagne. Careful chemical analysis might show that both of these possessed the same amount of alcohol, of mineral and organic salts, and of organic acids, even to the fraction of a grain, yet how essentially different the two articles would be! Neither chemical analysis nor microscopical study could reveal the many essential qualities involved in the words maturity, bouquet, and flavour. Notwithstanding this, the ordinary senses of taste and smell could discover what the two branches of science could not. Burton water contains from 60 to 80 grains of mineral matter per gallon, the beer from it containing from 200 to 300 grains, the quantity having been increased by the concentration during boiling, and by the salts extracted from the malt and hops. The greater part of the original 60 to 80 grains consists of alkaline-earthy salts, and the distinguishing characteristic of Burton water is its high degree of permanent hardness. Edinburgh brewing water has generally the same qualities though much less marked, whilst London and Dublin brewing waters are distinguished by the almost entire absence of permanent hardness, and by only containing about one-third of the mineral matter that is found in Burton water. It has been alleged that brewers using hard water are at a disadvantage in having to pay for the extra density of the water used. This matter has been greatly exaggerated. It must be remembered that the heating and subsequent boiling operations greatly reduce the original hardness, and that the charge is always taken from wort which has been thus treated. Moreover, leaving this important modification out of the question, it would still be necessary for a water to contain about 140 grains of mineral matter per gallon in order to give it at 60° F. an extra degree of gravity. A brewing water with 140 grains of salts per gallon would indeed be a curiosity. Taking the average specific gravity of the mineral salts to be as high as 2, then for each grain present in a gallon the gain in weight would only be half a grain, because of water displacement. With the carbohydrates a water might contain about 180 grains per gallon, and yet only gain one degree of gravity. Brewers who have made complaints on this subject have taken the water's gravity just as it came from the supply, perhaps at only 50° F., not at the standard 60° F.

In the general construction and planning of a brewery the following details are specially worthy of consideration:—the relative positions of

the various utensils, vessels, stores and cellars; their aspect in regard to wind, sun, smoke, steam; the nature of the roof, the amount of ventilation, and the exposure of the plant and stores to extremes of temperature. As in a malthouse, taking the cistern capacity for a standard, the areas of the couch, the floors and the kilns must be regulated according to the known swell of the grain; so too the same holds good in a brewery between the mash tun, the copper, and the fermenting vats. Not only the relative capacity of the vessels but also their shape, the materials of which they are made, the position of their inlets and outlets all demand the brewer's attention. Many breweries of old construction present great anomalies in these respects, either from want of judgment or from too limited a space or capital, though in other cases the necessities of the time requiring the erection of new vessels, &c., as the business increased, have resulted in a heterogeneity which is bewildering, often necessitating further arrangements, which are very inconvenient if not positively dangerous. A few of the most important details may be more closely pointed out. Thus, the ceiling should be arranged so as to ventilate but not so as to act as a condenser of steam; rooms for storing grain, malt and hops should be dry and kept closed; the cold water cisterns are found most convenient when placed at the top of the building, so too the ground-malt stores, and these should be conveniently situated as regards the malt hopper, this in its turn commanding the mash tun. The hot water cistern should also command the mash tun. Cast iron and wood (oak and fir) seem to be the rival materials for most of the utensils, the copper and the refrigerator being made generally of copper, and the fermenting vats frequently of slate or of stone. Wrought iron in consequence of rust offers objections, but it is used for hot water cisterns. The size of the mash tun is chiefly regulated by the proposed scale of brewing, so many quarters at a time, sufficient space being allowed for the brewing water and for the swell of the goods. A moderate depth only is desirable, both for mixing and for draining; the best shape for the mash tun and for other vessels being the round one, corners are thus avoided in which accumulations might occur and in which mixing is difficult. The perforations in the mash tun's false bottom are about one-sixteenth of an inch wide, and the tun should have convenient outlets for the grains, so that their removal by manual or machine labour is accelerated. The mash tun should command either the underback or the copper. In the copper, space must be allowed for expansion and for frothing of the wort, and in the fermenting vats space for the yeasty head, and these latter should be protected by partitions or otherwise from steam generated in the boilers, mash tuns or coppers; the fermenting rooms, as also the cleansing rooms, being kept as cool as possible.

6.—MASHING.

(A) *Principles of the Mashing Process.*

Whatever other objects the brewer may have in view, and whatever kind of beer he may wish to produce, the greatest amount possible of extract is always required from the malt. To effect this successfully, the temperature in all its stages—initial, progressive and final—must be regulated, as also must the time of infusion, whilst the quantity of

water must at any rate be sufficient to ensure a thorough mixing. There are, as has been already said, as many varieties of beer as there are of wine; strongly alcoholic beer may be compared to dry wine, whilst beer containing more unfermented saccharine and dextrinous matter, as well as more nitrogenous matter, may be compared to full-bodied and sweet wine. *These future quantities can be far better governed in the mash tun than in the fermenting vat*, so that whether the beer is to be an alcoholic stimulating one, or a full-bodied nutritious one, can be thus early determined by the brewer. Means for readily regulating the tempetature of the mash, either by letting in steam or water at any temperature, or by the use of attemperators, confer great power upon the brewer and enable him to completely govern his product; neglect of the use of, or inability to employ this power, is a source of danger. Many, many years of experiment on a practical scale, and of scientific investigation on a smaller but more searching scale, have fixed for brewers what are the best conditions for mashing, so as to secure quantity and quality in beer. Assuming a thorough mixture to have been made in the mash tun, the temperature becomes the most important factor, whilst the time of infusion and the quantity of water exert their lesser though important influences. Two hours' mashing extracts far more from the malt than one hour's, and seven hours' more than two hours', but two to three hours' mash though yielding less than seven hours' is for practical and economical reasons the most preferable. Again, at the proper temperature, the greater amount of starch in the malt is almost immediately converted into dextrin and maltose, though a prolongation of the time of infusion, slowly and still more slowly completes the transformation of the dextrin into maltose. Thus, in half an hour's mash at the proper temperature, 80 to 90 per cent. of the starch is converted to maltose, the remainder being dextrin, whilst a mash continued for two hours gives much the same, though not quite, such high results as a five to seven hours' mash,—about 82 per cent. of the starch being thus converted to maltose; if the mash were continued for double the time, say for fourteen hours or more, then nearly all the starch is changed into maltose. By prolonging or shortening the time of infusion it appears then that the amount of extract is governed, as is also the relation of maltose to dextrin in that extract. The results of many accurate experiments on these points have been published by Dr. Graham, of University College, London. Two or two and a half hours' mash gives both in quantity and quality practically the same results as a five to seven hours' mash. The amount of water to be used is another consideration. Here it may simply be repeated that enough water to ensure thorough mixing and draining will secure the most satisfactory extracts, though the addition of more and more water at the proper temperature would doubtless almost for ever extract or wash out more from the malt, as well as help to complete the conversion to maltose. The subsequent boiling down of such a large quantity of water has however to be considered. Experiments on a large and small scale have fixed the best relative quantities of water and malt, and the quantities used at breweries yield practically the same results that much larger quantities of water would yield. The temperature, however, acting simultaneously with the conditions of time and quantity of water, has a far more important effect than either of these other conditions. Before discus-

sing this point in its practical bearings, it is necessary to enquire more precisely into the subtle processes which accompany and which cause those effects which are made apparent to us. This most interesting employment is most necessary for the proper understanding of the main results. Allusion must be made to a subject referred to in the malting process. Changes inherent to that process have it was shown, conferred upon the soluble and coagulable albuminous matter of the grain, a power called the diastatic power. The albuminous matter possessing this power, and called popularly diastase, has by some been classed along with many other bodies as a ferment. But whereas the diastatic ferment exhausts itself by exercising its function, the yeast cell and other ferments continuously propagate themselves. Investigation having shown this and other great differences to exist between the diastatic and the other well known ferments, it has since been distinguished as a non-organised ferment, a soluble and indirect ferment, and classed as a diastatic ferment with several other animal and vegetable diastases, (such as saliva and the gastric juice) all of which have the peculiar power under favourable conditions of converting starch into sugar. Limits have been placed to this power upon starch as exercised by the albuminous matter of malt, but the correctness of such restrictions is doubtful, for the power varies greatly when equal quantities are taken, and is greater or lesser moreover according to a certain range of temperature. A special study is necessary to explain the creation of this power and its exercise, especially so in regard to the changes the diastase itself undergoes whilst performing its special function. The exercise of the power is supposed to synchronise with the exhaustion and gradual decomposition of the diastatic albuminoids, such matter being very liable to change. Whatever may ultimately be proved as to this point, the effects upon the starch are much better known. Although the absolute molecular weight of starch is scarcely yet established, its relative or proportional composition is well-known. It consists of atoms of the elements carbon, hydrogen, and oxygen, in the numerical relation of 6, 10, and 5, or of 12, 20, and 10. Dextrin is similarly constituted, whilst cane-sugar and maltose consist of the same three elements in the atomic proportion of 12, 22, and 11. The difference in the proportional constitution of the two bodies—starch and maltose—consists in the latter having two more atoms of hydrogen and one more atom of oxygen in each molecule, and as a molecule of water consists of two atoms of hydrogen and one of oxygen, it is usual to say that starch and maltose only differ in their relative composition by the latter containing the elements of an extra molecule of water, though of course there are many other differences between the two bodies. The diastatic body acting upon starch produces from it dextrin and maltose, ultimately maltose alone would remain. The more favourable the circumstances of temperature and of thorough mixture and solution, the more quickly are these changes effected. It had been supposed that this conversion was a far simpler and straightforward process than it really is, and that the starch molecule merely underwent hydration at once, that is, that it simply took up a molecule of water, or the elements in this proportion, and so became maltose; and if C. 12, H. 20, O. 10, were the formula for the starch molecule, and C. 12, H. 22, O. 11, that of maltose, the assimilation was thus easily explained. But the conversion process has recently been shown to be far more complex

than this, although the previous explanation now known to be incorrect marked a great step in advance upon former knowledge. Starch, so far as it is possible to observe it, seems to produce dextrin and maltose simultaneously when undergoing conversion, but the relative proportion of these products is always changing. Moreover, dextrin is a generic name, for there are probably nine varieties of it, all of which vary in molecular weight, and in some other particulars, notably in their specific rotatory power, and their action in regard to free iodine. It is probable that starch during its transformation to maltose passes through ten stages, the original starch molecule being step by step degraded in molecular weight through a series of dextrins to the final product maltose. A valuable paper in the Journal of the Chemical Society for September, 1879, has elucidated this subject. Such then is the action of diastase upon starch. Time and thorough admixture have been shown to promote the completion towards the final product, maltose, but the temperature is the greatest controlling power. It seems that the active albuminous matter is soluble in cold but probably more so in slightly warm water, the temperature of 120° F. or a little below this, being a very favourable one. As the water's temperature gradually rises, the albuminous matter is likewise gradually coagulated and thrown down, so that in water at 140° F. about 50 per cent. of the albuminous matter is rendered either completely or to a great extent powerless to effect the conversion of starch; at any rate the total original power has diminished 50 per cent. At 177° F. (a long way from the boiling point of water) all diastatic power ceases, and at 212° F., practically all the albuminous matter coagulates and is precipitated. If the starchy matter could be first extracted from malt, and then afterwards the diastase were allowed to play upon it, a temperature of about 120° F. would be the most favourable for the conversion; in half-an-hour probably 80 per cent. of the starch would have reached the maltose stage. This fact (as it will be shown) is of great practical importance when raw grain is used, but the double problem when malt alone is used, is to extract the starch first and then to convert it. To extract the starch, to burst its cells, and to render it at all soluble, the temperature must be at least 140° F., and in practical brewing there is the grain's cohesiveness to overcome, and the obstinate husk to be likewise raised in temperature, so that the malt and water mixture is found to give the best results when the combined mass is at a temperature of 150° F., the starch being then brought to a condition for the diastase to act upon it. The starch cells of malt are, however, probably more easily burst than those of raw grain; the malting process, especially the kiln-drying, having weakened the tenacity of the cellulose coverings. By employing the necessary temperature of 140 to 150° F. for the mixed mash, a considerable part of the diastatic power is certainly sacrificed; but experiment alone can indicate which is the lowest mashing heat that can safely be employed in order to get the largest amount of extract and dissolve the starch, and which at the same time can utilise the highest possible amount of diastatic power. No doubt if the diastase could have full play it would help the starch conversion before the temperature 140° F. (at which the starch cells are burst) were reached, but under the circumstances of the case it cannot have this liberty. Dr. Graham's experiments with miniature mashes, show that when 140° F. is the highest temperature the mash

ever reaches, the most extract is obtained, and the largest amount of maltose is formed, though 150' F. as the maximum gives very good results too. If the mash is gradually raised from moderate temperature to these points 140 to 150° F., the best results are obtained both as to amount of extract and as to sugar proportion. Under these circumstances the mashing occupying two-and-half hours, over 80 per cent. of the starch extracted became maltose and the remainder dextrin. In the after process of fermentation the maltose easily yields alcohol, but the dextrin does this much more slowly, so that the more dextrin there is in the wort and consequently in the beer, the fuller body the latter will have, and this kind of beer is preferred for stock beer, or for export, as it has better keeping qualities than other beer. The brewer can vary by means of temperature the amount of dextrin and of course of maltose in the wort. The most favourable temperatures for producing little dextrin and much maltose are also the best for procuring the largest total extract. What then the brewer requires who brews the full-bodied dextrinous beer is, to get this quality without sacrificing more extract than is absolutely necessary. This he can do by having a higher mashing temperature, for by this means diastatic power is rendered slow and feeble, but another danger will begin to appear if this operation is not skilfully carried out, for too high a temperature killing off as it does the diastase, renders the conversion of the starch even to dextrin more and more precarious, so that although a high temperature may dissolve out all the starch, there will be the risk of finding some of it in the wort after cooling, the starch at the colder temperature re-appearing and rendering the wort turbid. To avoid this kind of thing, and yet to obtain the dextrinous wort, it has been found best to limit the time during which the quickest conversion of dextrin to maltose can transpire, and this is done, not by commencing the mash at too high a temperature, but by commencing as usual, raising the temperature gradually to near the most favourable maltose-forming temperature, allowing this condition to prevail but for a short time, and then quickly raising the mash to a point at which the diastatic power, though not effectively destroyed, is yet rendered somewhat weak; finally the mash is kept at this exalted temperature for a sufficient length of time. Another way of managing this kind of brewing is by limiting the mashing time to one-and-a-half instead of the usual two or two-and-a-half hours. It is impossible to avoid loss of extract when beer of this kind is brewed, for all the circumstances of time, temperature, and quantity of water, which give most extract, produce also the most maltose—Dr. Graham has proved this; the German brewer carries out this sort of brewing in producing his lager beer. Skilful management can minimise the loss of extract, and practical brewers have their own experimental data to guide them in doing this.

(B) *Practical Details of the Mashing Process.*

The use of hard or soft water is a matter of far greater importance in mashing than in malting. Hard water is preferred for ales, its final effect being to clarify them and render them brighter; soft water has its advantages for porter and stout. When accuracy is studied in regard to the quantity of water to be used with each quarter of malt, with the view of obtaining wort of an approximate original gravity, the number of barrels of water to be let into the mash tun is measured off

by means of water gauges connected with the hot liquor tank, or by means of floats or of other contrivances showing the number of inches or of barrels of water in these previously gauged vessels. Whatever temperature the mashing liquor is at, its volume at 60° F. can be known at once by reference to tables, the expansion of water for each degree of temperature being exactly known. The quantities of water for the first mashing, for raising the temperature of the mash, and for subsequent mashings and spargings, are all to be considered. To arrive more exactly at the desired original gravity, a supplementary calculation can always be, and probably is, always made when the wort reaches the copper, for allowances must be made for the retention of much water by the goods, for loss during boiling, and for varying qualities of malt. The malt gives greatest satisfaction when it has been crushed by plain metal rollers, grist otherwise prepared presents difficulties in the mixing and in the draining. To prevent stopping up the holes in the false bottom, a little water is first let into the tun, and then the malt and water together. *Thorough and prompt mixing is most desirable.* Too sudden a contact between any part of the grist and an overwhelming quantity of hot water, whilst other parts are barely touched, must be avoided, for a sudden shock at a high temperature coagulates the albuminous matter before it has had the opportunity of displaying its diastatic power. It is most important in mashing, that the whole mash both at first and throughout should have a uniform temperature, and hence the advisability of letting the water and the grist meet together gradually. It is not usual to add all the mashing liquor at one time, nor would it be wise to do so, for as the mash is properly allowed two to three hours to complete itself, it could only be by means of sufficient attemperating power that the necessary gradual rise and the usual fall in temperature could be brought about. The mash is thoroughly mixed all the time the ingredients are being let in. In some mash tuns, to effect thorough mixing, the grist and water are brought intimately together by a machine fixed over the mash tun, and called a masher, the mixture is then delivered into all parts of the mash tun. This arrangement is used, either as a substitute for the internal rake machinery, or as a preliminary to the internal mixing. Another common plan is to have the exits of the malt hopper and of the water pipe from the tank impinging upon one another over the mash tun. When the water is mixed with the grist, it is found that the temperature of the mixture is 10 to 20° F. below that of the water used, because the water has to raise the grist to a much higher temperature than it previously held, the temperature of the mash being the resultant of that of the grist and of the water respectively, governed of course by their respective specific heats, and by other minor though important considerations, as well as by the more obvious cause of the respective quantities. The mash tun and its fittings have to be raised to the temperature of the mash; in cold weather a higher temperature is used than in hot, whilst even the mash-tun's material is considered. The quality of the malt, and the kind of beer to be made (ale or stout, store beer or otherwise), govern the initial as well as the main and final temperatures. When the mash has settled down to one general temperature, the tendency would be for this to gradually decline, owing to loss of heat. The chemical action however going on in the mash, through the diastatic power exerting itself upon the starchy materials, and also through the

act of solution of the maltose and dextrin formed, retards in several ways the looked for loss of heat, by itself creating heat. The author of the *Manual of Brewing* has explained another fact well known to brewers, namely, that in order to produce a given temperature of mash, the temperature of the water when pale malt is used must be higher than when much or all amber malt is used, the chemical action in the latter cases being greater, because amber malt during the kiln-drying at higher temperatures than pale malt has parted with the molecules of water which accompany the starch molecules, hence, in mashing, it is ready to assimilate more water and thus to produce more heat. So, too, the same author shows that moist or slack malt requires the temperature of the mashing water to be higher to produce any given initial mash temperature. Usually, one-and-a-half to two barrels of water are at first used to each quarter of malt, frequent temperatures of the former are from 155 to 170° F., regulated by all the conditions alluded to. When thoroughly mixed, the mash is found to be from 140 to 155° F., 145° F. being a very good initial mash temperature. The higher the initial mash heat the larger will be the dextrin proportion in the wort, and if the temperature approach 170° F., starch will almost surely remain in it. When the first mixing is thoroughly effected, it is a frequent practice to let in another barrel per quarter, either below the plates when it forces up what liquor has settled there, or at the top. This second supply is at about 200° F., and it raises the temperature of the whole mash to 160 or 165° F. The mash as at first made, say 145° F., is hot enough to cause the breaking up of the starch cells, and is not too high to weaken considerably the diastatic power. Practical knowledge at each brewery must decide the exact or approximate temperatures. The water at 200° F. is wisely added afterwards, if used at first, solution of albuminous matter would be impossible, but after this is once dissolved and the starch cells are burst, the only object is to secure the interaction with produces dextrin and maltose. The water at 200° F., by raising the whole mash to 160 or 165° F., still allows this action to proceed rapidly. The heat now gradually falls, but should not be allowed to decline below 150 or 152° F. A good final heat is desirable because less time is spent in boiling, draining is more effective, and the danger from disease ferments is avoided, for these require lower temperatures than 150° F., though this danger is small indeed if the boiling is properly carried out. The wort after about two hours is let off into the copper, either directly or through a vessel called an underback, whence it can be conveniently pumped into the copper. The grains are then treated with more liquor at a slightly higher temperature than the first mashing liquor, say 170 to 175° F., bringing them to about 160° F., so that the conversion may be completed; moreover, the object is to thoroughly soak out and drain the goods, to leave as little extract as possible imbedded in the stratum of goods.

Another excellent plan for a mash is as follows:—One-and-a-half to two barrels of liquid at 170° F., or a little lower, are used first, ensuring an initial mash of 150° F., this, after thorough mixing, is left for two hours; if the temperature falls lower, a little hot water is let in. The wort is now drawn off and a second mash ensues, with water at a little higher temperature than the first, say 175° F., and this gives in its turn a mash of 160° F. Or sparging may take place, with water at this temperature, 175° F., either in addition to or in lieu of the second

mash. These temperatures, whilst extracting any starch left behind, allow also of the exercise of the converting power, whilst the process itself ensures thorough draining. Whenever a second mash is resorted to, or in its place or subsequent to it sparging is employed, the object should not be to extract more starch from the grain, unless such second mash or sparging operation is performed with water of a sufficiently low temperature to allow also of the starch's conversion; to merely extract the starch at the temperature of 170 to 180° F. and to drain it off into the copper, is sure to cause many difficulties in the after cooling and fermenting, for such starchy matter has then little or no chance of being converted. Hence a second mash, or sparging in its place, is far more serviceable when the temperature but little exceeds that of the first mash, for the action of the first mash is not only completed, but the goods are as well drained from all mechanically suspended matter with water at 160° F. as with water at 180° F. A high temperature second mash or sparge is a source of danger, and it can in no wise remedy a previous bad mash, though it is sure to spoil a previous good one. If, however, the sole object of the second or of any subsequent mash or sparging, at temperature of 180 to 190° F., be for the purpose of extracting the starch and then using the wort, draining off as liquor for an entirely fresh mashing at the proper temperatures, then instead of it being objectionable it is to be recommended, any starch which such wort contains will of course be converted in the next brewing.

7.—BOILING AND HOPPING.

Boiling is commenced as soon as possible after the wort leaves the mash tun. Several objects are effected by it, the principle one being the extraction during boiling of the bitter and preservative principles of the hops, the hops being mixed with the wort in the copper. Again, the length of the gyle is regulated in the copper; if too much water has been used boiling is continued longer, if insufficient has been used to bring the wort down to the required gravity more water can be added here. Boiling, moreover, effects a thorough mixture of the substances extracted from the malt and from the hops, forming a homogeneous whole. It aids, too, the thorough solution of some of these substances, whilst it causes the precipitation of other bodies, which by their presence in excess would impair the keeping qualities and the appearance of the beer. The precipitated substances consist chiefly of coagulated albuminous matter, for some of this latter is still soluble at the temperature at which the wort leaves the mash tun. The tannin extracted from the hops also aids in the precipitation, and what albuminous matter escapes precipitation here is greatly modified and digested by the boiling, so that of the 11 per cent. present in the original malt only a small modified and digested residue escapes the fiery ordeal. Resin, colouring, and mineral matters, are also precipitated, especially those salts which gave temporary hardness to the original water. One more object effected by a thorough boiling is the destruction of disease germs, of moulds, and of dangerous organic impurity which may previously have existed in the water, or may have come from the materials or from other sources. If boiling be carried on with closed covers this is performed more completely; besides, when

this improvement is adopted, less of the valuable but volatile aromatic oil of the hops escapes by evaporation, and probably economy in heat is also ensured. Boiling is thus shown to be a very useful process. The time in the copper is regulated by the length of gyle required, as well as by the quantity of wort actually in the copper, but the actual boiling should occupy in any case two hours. Copper accommodation should be such that no wort is left over merely waiting for the first quantity to be boiled, and if the copper is meant to hold all the wort from the various mashings and spargings, its capacity should be at least three barrels per quarter of malt used. Steam jackets are used sometimes instead of fires for heating, and claim to prevent burning.

The quantity of hops employed varies greatly. It varies with the kind of beer brewed, whether bitter ale or otherwise, with the quality of the hops, and of course with special reference to the last hop season it may be added, with the price of the hops. Broadly, the quantity used varies from two to twenty pounds per quarter of malt, in porter and stout the quantity is about six pounds more or less. Sixteen pounds per quarter, and one or two pounds extra in each cask, are sometimes used for English bitter beers. The essential bitter of hops is called lupulin, and it is chiefly contained in the small yellow globular glands which abound at the bases of the leaves. Lupulin gives to beer the bitter and narcotic properties and the aromatic smell. Hop extract generally acts as a tonic, and it is, Pasteur says, a valuable preservative against disease ferments; its action upon ordinary yeast would, especially when there were excess of it, tend to weaken the yeast. Besides lupulin, tannin, resin and oils are extracted by boiling. Hops contain besides 5 to 8 per cent. of mineral matter, chiefly phosphates, sulphates, chlorides and carbonates of lime, magnesia and potash. Much of these matters so extracted is soon precipitated; the tannin is said to ally itself with part of the wort's albuminous matter, and hasten the precipitation of this by forming tannate of albumen. Prolonged boiling extracts substances which give a rank odour and taste to the beer, so that if longer boiling than usual is required merely to concentrate the wort, the hops need not be added till the operation has been going on some time. The hop leaves and the residue from boiling are strained from the wort before or during cooling. Sometimes a strainer for this purpose covers the discharge cock of the copper, being made of the same material as that vessel. Often the cooler is itself the strainer, and has a number of perforations in its bottom which will not permit the hop leaves to pass through. Other times the straining is performed by sieves of various size and shape placed above or in the cooling back or elsewhere. The high price of hops has caused suggestions to be made or repeated for economizing their use. One of these is to partly pulverize or break up the hops by stripping leaf from leaf by manual or other labour, with such precautions that none of the powder is lost; the boiling wort can then extract more completely the bitter and other principles. Another plain is to boil the hops in two successive brewings. Hop-presses have been largely used for some time for squeezing out the wort from the boiled hop leaves. The leaves are occasionally sold for manure, and as there is imbedded in them much of the precipitate albuminous matter, as well as precipitated salts, they must be of some value for this purpose, either alone or with the stable manure.

8.—COOLING. DANGER FROM DISEASED FERMENTS.

The wort from the copper must be cooled as rapidly as possible from the boiling point to the temperature at which yeast is added to it to start fermentation. This desirable point is called the pitching point, and it ranges from 57 to 60° F., according to the weather and other circumstances. The cooling process is conducted in several ways. One well-known system is to expose the wort to the air in vessels having large areas but shallow depths, the cooling being accelerated by revolving fans, which thrust off the steam and draw fresh and cold air over the wort's surface. In hot or mild weather, ice is placed in convenient floats or is fixed in certain positions to hasten the cooling. Improvements to hasten this process have been introduced from time to time. One plan was to pass the wort either through or over copper pipes or flat coils, whilst cold water passed on the other side of the pipe or coil; a plentiful supply of cold water averaging between 50 and 60° F. is most valuable. The present magnificent refrigerators, horizontal and perpendicular, are improvements upon this previous system. In some cases, when the water supply is sufficient but its temperature is too high or is not constant, artificial cooling of it has been successfully carried on, either by ice, or by solutions of ether, sulphur dioxide, or of other gases. These solutions are made to evaporate, and suitable appliances distribute the cold thus produced. The usual refrigerators are of copper; this being a first-rate heat conductor renders the interaction of the hot wort and the cold water very rapid. The cooling, in fact, is very rapid down to the temperature of the water used—the wort passes along an array of flat copper tubes fitted into a suitable frame, and at the end where the wort passes off towards the fermenting vessels the cold water enters the interior of the tube, and it passes to the end where the hot wort is just arriving. The heat so acquired by the water is not wasted, but the nearly boiling water serves to feed the boiler where water is heated for cleaning purposes. With some of these refrigerators the wort can, by easy contrivances, be cooled to any desired temperature above that of the cold water. Sometimes very cold air is used in place of water. When cooled, if the wort appears clear it is a sign of a good mash, so far as the mashing temperature is concerned, and of good boiling, and it proves the absence of starch, whilst a permanent cloudy appearance is a bad sign, may be the result of one or many defects, may indicate the presence of starch or of finely divided but unprecipitated albuminous matter, the latter resulting through insufficient boiling. Besides the bringing down of the wort to the proper pitching heat, the great object of cooling, especially of rapid cooling, is to place the wort at a temperature below that at which disease ferments can do effective harm. If the wort were free from these to begin with, and if the air were pure (that is to say for brewing purposes) and free from these ferments, exposure to air during cooling would do no harm. But disease germs often exist at breweries, are brought in with the grain or the hops, or from hay-lofts, or with finely-pulverised dust from decaying matter, thus they get into the air, the wort, and the yeast, and on to the vessels, &c. They may be introduced for the first time into the wort by the yeast itself. The danger to the beer is greater in mild and hot weather. These germs, of which there are several well-known kinds, distinguished under the microscope by

their specific forms, deposits or residues, or by their specific results, are able in a suitable medium (and wort is a most suitable one), and at certain temperatures, to flourish, and thereby cause other fermentations to set in than the normal alcoholic one of the yeast ferment. The ever-varying nitrogenous substances in wort, together with the due quantities of alkaline and alkaline earthy salts, seem to afford fit nourishment for these many varieties of germ life, and wort becomes at proper temperatures a rich breeding place. Between certain limits of temperature, each particular ferment in its turn has the best chance of surviving in the struggle for existence, to the partial or almost total exclusion of each other kind, though all of them can be submitted to great extremes of heat and cold, especially when dry, without being utterly destroyed; still, for active propagation, besides the necessary food certain small limits of temperature alone are favourable. These ferments are distinct forms of life, animal or plant, and cannot change one into another, though different circumstances favour the production or the modification of one or the other. The butyric ferment, which can in suitable circumstances produce butyric acid from lactic, tartaric and other acids, can also do this from saccharine and starchy bodies, especially between the temperatures of 77 and 95° F., or a little higher, though it is still active at somewhat higher temperatures, but like other ferments it is killed when temperature reaches 128 to 140° F., especially if alcohol be present. The lactic ferment is most active at the same temperatures, 77 to 95° F., and less so both at higher and lower temperatures; it produces chiefly lactic acid from the sugar. The mannitic or viscous ferment flourishes at much the same temperatures, producing from the sugar, gum and mannite. In the presence of alcohol the acetic ferment flourishes between 76 and 82° F. In all these cases, as in that of the usual alcoholic fermentation, carbonic acid and other gases are generated. The yeast ferment though active at 46 to 50° F. is most active at 77 to 86° F., but at these high temperatures the disease ferments are pretty sure to accompany it. In the dry state yeast can exist at temperatures just above the freezing point, and just below the boiling point of water. Pasteur, who has shown all his admirable qualities in studies of this nature, informs brewers that every unhealthy change in the quality of beer coincides with the development of microscopic germs, alien to the pure ferment, and that proofs of these having existed can be found in wort and beer residues along with the ordinary deposits of resin, colouring matter and yeast. Pasteur has described the chief of these ferments, and has given excellent diagrams of them or of their residues, and the microscope will reveal them either in the deposits, the finings, or along with the yeast cells in the new yeast. The products of these ferments are acid, putrid, viscous or bitter, and they give a characteristic taste or smell to the beer. It is plain that though all these abnormal ferments can exist between 32 and 140° F., yet the temperatures at which they are most active are much above that required by a wort for a healthy alcoholic fermentation. Hence the wisdom of reducing and keeping the wort below these temperatures. Whilst fermenting, the wort should never exceed 70° F., by this caution the disease ferments are rendered very weak, and their action sluggish, whilst the yeast is itself very active and will monopolise nearly all the food in the wort, upon which it as well as the disease ferments exist, so that the latter are gradually

starved out, and become incompetent of surviving the struggle for existence. Although the cooling operation is one in which the disease ferments are very likely first to take root in the wort, yet their action may be continued, though in a more feeble manner, throughout the entire period of alcoholic fermentation. The acetic ferment especially may be active all this time, and the effects of this and of the others will show themselves in the finished beer. The disease ferments, however, may not start until the alcoholic fermentation has mainly ceased.

9.—FERMENTATION.

(A) *Introductory.*

This subject considered practically, or studied scientifically, is the most difficult and the most complicated part of the whole brewing process. Some say that it is also the most important part of the process, though others consider the mashing to be of equal if not of greater importance. In the sense that the fermentation is a very difficult operation to manage satisfactorily, and considering too that the wort during this and the previous cooling operation is most sensitive to changes, both from within and from without, so that danger to the beer's quality is most to be apprehended, the wort moreover undergoing changes both in its chemical composition and its physical condition,—considering all these things, fermentation undoubtedly requires to be watched with continuous anxiety, and is a highly important operation. But assuming a thorough acquaintance with these difficulties and dangers, and assuming the possession of the knowledge how to meet or prevent them, this operation then becomes inferior in importance to that of mashing; for if the primary operation has been badly performed, or if the boiling has been incomplete, the most skilful management during fermentation can but slightly atone for the previous neglect or misfortune. Thus the presence of starch or of suspended albuminous matter cannot be remedied by fermentation. Moreover, by the mashing taken with the boiling the distinct character of the beer is marked out beforehand—whether it is to be an alcoholic, stimulating beer, and therefore one susceptible of exhaustive fermentation, or a dextrinous, full-bodied one, in which fermentation will be comparatively slow, continuous, and incomplete. By perseverance and skill the beer's character in these respects may be governed to a limited extent by the fermentation, and in spite of the mash, but this can only be done by an economical failure—by the sacrifice of extra labour and expense. Broadly, it may be said the mashing governs the beer's future character, the fermentation, though it may partly regulate this, generally travels in the lines marked out for it by the primary process.

Fermentation may be said to commence with the addition of the yeast to the wort, and to continue uninterruptedly till all the fermentable matter has been decomposed into alcohol, carbonic acid, and a few other products, and until such as is not decomposed has been otherwise changed and rendered unfermentable. The action gets slower and weaker as time goes on, but in beer which passes rapidly into consumption it must still be active when the consumer gets the beer. The cleansing process too may begin, and often does, as soon as active fermentation has produced any considerable amount of yeast, though

usually it succeeds what is for revenue purposes distinguished as the fermentation process, though during the cleansing operation fermentation may be still very active. It may be shown, too, rather as an interesting fact, that one of any practical bearing that fermentation (alcoholic or diseased) may start in wort even before yeast is added to it, this fact some years ago would have been adduced as an example of spontaneous fermentation. Spontaneity, either in generation or in fermentation, is no longer believed in, and although the term spontaneous might be applied to a fermentation so starting, yet no one would doubt that the fermentation was caused by ferment germs having found their way into the wort.

The fermentation process however, as the brewer speaks of it, is confined to that operation only whilst it proceeds visibly and rapidly in the fermenting and cleansing vessels. It commences soon after yeast is added, and it continues till the wort has attenuated to near the gravity at which it will permanently remain. What takes place in the cleansing vessels besides fermentation is best considered under the heading of cleansing.

(B) *Practical Details of the Fermentation Process.*

The yeast comes in contact with the wort in the gauged fermenting vessels; the two are thoroughly mixed together, and a good way of ensuring a thorough mixture is to add the yeast to a convenient quantity of the wort in a tub or a pail, and when a mixture has thus been obtained to add this mixture to the main body of the wort. Experience has shown that a temperature of 56 to 60° F. is the best for the wort. The quantity of yeast used with a certain bulk of wort should be governed by the quantity of extractive matter in the wort, and the wort's gravity affords a good and a ready comparative indication of this quantity of extractive matter. The yeast used varies from one-and-a-half to three pounds per barrel of wort, and it decomposes from twenty to forty times its weight of saccharine matter, though much of this decomposition must be effected by the new yeast produced during the process, not by the original yeast added; moreover, these quantities vary with what is considered to be the proper standard dryness for yeast. Wort prepared largely from cane or other sugar, and wort from raw grain, or wort for porter and stout, require different proportions of yeast to ordinary malt wort for ale, but in all these cases a little experience is worth a great deal of theory, moreover, these various kinds of wort can be satisfactorily fermented as much by proper regulation of time, heat and other conditions, as by the mere quantity of yeast. All the yeast need not be added at once, more can easily be added if required, whilst if too much has been used it is a more difficult matter to retard the process, nor does excess of yeast improve the quality of beer. Attemperators are of great service in these respects; if fermentation is too active and a consequent rise in the wort's temperature occurs, it can, by these appliances, be brought down again, and the dangers from diseased ferments diminished. The maximum temperature during fermentation should not exceed 70° F. Besides lowering the temperature, there is another way of retarding a too active fermentation, namely, by removing the yeast as soon as it is formed; this can be done by the skimming methods in vogue, or by letting the wort off into cleansing vessels or into smaller fermenting vessels, the

decrease in bulk then having its effect upon the wort's temperature besides encouraging the rise of yeast and facilitating its removal. For healthy and regular fermentation the wort should only be of a moderate depth, otherwise sluggishness as well as inequality is likely to result in consequence of insufficient air. Moderate aeration of wort is considered to be a practical stimulant to fermentation, though too much air weakens the yeast and gives it a tendency to become a mould. Arrangements which effect moderate aeration and at the same time rouse the wort are much used, though at other times pumping the wort up and letting it down again is resorted to for the same purpose. If fermentation proceeds too slowly, it is encouraged not so much by adding excess of yeast as by nursing the wort, by keeping it close and snug after it has had a good rousing, thus raising the temperature. At other times the wort is dressed with a little well ground meal of malt, barley, or beans, a handful or so of this being mixed with the wort. The meal contains food for the yeast plant, but such dressing, though undoubtedly of value in some cases, should not be adopted indiscriminately to remedy all sluggish fermentations. If the wort is good, but the yeast poor and weak, then dressing may be serviceable; so, too, when fermentation is to be carried far, the dressing renews the languishing yeast, but if the wort has been improperly made, dressing can do but little to remedy the evil of consequent sluggish fermentation. There is great latitude in the extent to which fermentation is carried, for whilst some beers are only fermented through twenty degrees, others lose nearly seventy by the process. Nor does the beer's original gravity govern closely the amount of attenuation, but rather the kind of beer brewed does this. Taking beers of an average original gravity, say 1060°, whilst some are only fermented down to 1020°, others are so to 1002°, or even nearer than this to the density of water. Moreover, speaking generally, the longer beer is kept the further will fermentation proceed, though it gets slower and still more slow as times goes on.

But returning to the commencement of the fermentation process, when this has been going on for a few hours, yeast begins to rise, together with some finely suspended but insoluble fibrous and other matter derived from the hops during boiling, and this scum gives a black spotted or a brown appearance to the yeasty head. As the fermentation gets more active after several hours, the yeasty head gets gradually larger, the wort's temperature rises through a few degrees, and large volumes of carbonic acid gas are given off. The yeasty head is sometimes removed at once, at other times it is left lying on the wort till removal to the cleansing vessels occurs. If fermentation is rapid enough the yeast is removed periodically, if it is too fast the yeast should be removed as quickly and as thoroughly as possible, but if the fermentation is too slow the newly-formed yeast should be thoroughly mixed with the wort, this answers the purpose of adding fresh yeast. Rousing and skimming are thus regulated by the conditions of the fermenting process, and themselves regulate that process. The wort is often either partially or entirely protected from the cold, from the wind, or from the sun's heat, by covers; these precautions, like the former, regulate and are regulated by the condition of the fermentation. The fermentation may be carried on for many hours, may indeed be allowed almost to complete itself in what are recognised by the excise

as the proper fermenting vessels—this is of course according to the brewer's convenience—the wort may then pass direct to the final cleansing vessels. At other times the wort is conducted, after only a few hours' rest in the original vessels, to other fermenting vessels before it passes to the cleansing vessels. In many fermenting vessels arrangements are made for carrying off the excess of yeast formed. One good arrangement of the kind is the parachute, made often of tinned copper, the opening into this is fixed a short distance above the level of the wort, and as the yeast forms, it falls over into a receiver and is conducted by a tube to the yeast store. The arrangement can be raised or lowered to suit any level. Sometimes revolving arms are made to rotate at a short distance above the wort's level; these arms act as skimmers, and they push the yeast into suitable outlets. In other fermenting vessels the yeast is mainly left behind at the bottom, when the wort is drawn off (as it is done) a short distance above that bottom. The Yorkshire Square system of fermentation, practised in Yorkshire and elsewhere, combines in its mode of working three important advantages—it permits the excess yeast to be carried away; it permits rousing and aeration to take place; and it permits attemperation to be practised. Besides these advantages the wort is also protected from too much exposure. The squares are made of stone or slate, and are thus probably more easily cleaned than if wood were used, whilst the growth of putrid and diseased organisms on their surfaces is more easily checked. An inner square of the same material has at a certain height a horizontal stone partition, in the middle of which is a large opening. The wort is placed in the inner square, and when necessary it can be pumped by a small hand-pump into the upper part of this inner square; divided as it is from the lower part by the partition, the wort runs back at once through the hole into the lower part, thus good aeration and rousing are effected. As fermentation proceeds, the yeast rises through the hole and runs down a slope into a channel round the edge of the partition, and thence through a pipe to the yeast receiver. As to attemperation, this can be carried on both from the inside and the outside of the inner square—inside in the same manner as in ordinary fermenting vessels, and outside by placing warm or cold water as desired in the outer square, so that all sides of the inner one are surrounded; eventually the wort is drawn off into the cleansing vessels. The yeast produced is collected in troughs and reserved for future brewings; it should be kept in a cool, sheltered place, and various cooling methods are in vogue for the purpose. Overplus yeast is sold in its raw state for bread-making, &c., though large quantities of it, after being pressed and dried, are sent away for purification and conversion to German yeast.

(c) *Principles of the Fermentation Process.*

Though an intricate this is an interesting subject for study. It is unnecessary here to travel beyond the special subject of alcoholic fermentation as induced by yeast in beer wort. Disease ferments have been dwelt upon under the appropriate heading of cooling. Most of the changes which occur in fermenting wort have been long known, but more exact knowledge has only recently been acquired, especially so in regard to the life of the yeast cell. Careful observation on the part of practical brewers has taught them much in regard to fermenta-

tion, this practical experience has been handed down and extended and thus incorporated into the art of brewing. The acquirement of deeper knowledge was naturally beyond the scope of the trading brewer, for it required the devotion of a large amount of trained study. Attenuation was known to coincide with the decomposition of sugary and other matter, with the giving off of much carbonic acid, and the formation of spirit and of small quantities of acid, whilst the yeast was observed to reproduce itself in larger quantities than the amount started with. Lately, the products of fermentation have been the subjects of much scientific study, and a large number of bodies have consequently been discovered in various kinds of wort. Many of these exist (if indeed they exist at all) in such minute quantities that no practical interest need be attached to them, because their presence and agency have no practical effects demanding notice, whilst their detection is so difficult that their prevention or removal is impossible. Of the gases given off during fermentation carbonic acid forms the largest proportion, much of this gas too remains dissolved in the wort. Most of the fermentation products are derived from the saccharine and dextrinous matter, this applies to the carbonic acid. Of the alcohol produced, the principal part is ethyl alcohol, though other alcohols of the same series are probably formed in small quantities; the alcohol glycerin is also formed in all kinds of wort. Another class of bodies invariably formed is included under the term "caramel-like bodies." Like caramel itself, these are ill-defined carbohydrates of less specific gravity than the best known carbohydrates, and they are unfermentable. The acids are likewise formed directly or indirectly from the fermentable carbohydrates, either during fermentation or in the grain itself; amongst these there are succinic and lactic acid, whilst acetic and other acids of the same series are subsequently formed by the oxidation of the alcohols. Butyric and other acids, moreover, are formed by the agency of disease ferments upon sugar. Part of the fermentable carbohydrates remains undecomposed; the dextrinous matter is always more slowly decomposed than the sugar, though even maltose sugar is more slowly decomposed than the glucose sugars. The unfermentable residue helps to give mouth and fulness to the beer. Part of the carbohydrates is used up in forming the outer covering of the yeast cell.

Besides these products from the carbohydrates, there is a residue derived from the nitrogenous albuminous-like bodies of the wort. Of this nitrogenous matter, much is utilised in nourishing the yeast cell, part is rendered insoluble, and part is perhaps volatilised. It has been shown that the chief products of fermentation are carbonic acid and ethyl alcohol. If fermentation were carried to its furthest possible extreme in pure sugar solution, with excess of yeast, and with precautions against disease ferments occurring, still, other bodies than the two main products would be formed, whilst 1 per cent. more or less of the cane sugar would refuse to ferment. In fermentations conducted under these favourable laboratorial arrangements, from 100 parts of cane sugar or of maltose about 51 per cent. of alcohol would be obtained, but a theory demanding the complete fermentation would require the production of 53·8 per cent. of alcohol. Only about 94 per cent. of the sugar is decomposed into the two main products, the remainder besides nourishing the yeast forms the bodies previously alluded to. With dextrose solutions, very similar results have been shown. When, how-

ever, fermentation takes place upon the scale and under the usual conditions of practical brewing, the number of products is increased. These secondary products increase the attenuation, being lighter than the original saccharine and nitrogenous bodies whence they were derived. Leaving aside the more remote effects, the three chief causes of attenuation are :—the decomposition of the fermentable matter into alcohol and carbonic acid; the formation of the caramel-like bodies from the higher carbohydrates, and the exhaustion and precipitation of nitrogenous matter. It was formerly supposed that attenuation was the entire result of the first of these three causes, but the other two may increase the attenuation by as much as two or three degrees, for from three to five per cent. of the fermentable and other matter is changed into the unfermentable, or is exhausted. These facts have a practical bearing upon the present system for finding original gravities. Other, though smaller causes of attenuation are; the precipitation of mineral matter, the removal of suspended matter, and the formation of the minor quantities of acid and alcohol from the sugar.

Having dealt with the fermentable bodies and with the fermentation products, the ferment itself invites study. Yeast is one of many well recognised ferments, being the one whose especial function it is to create alcoholic fermentation, though this properly belongs in a less degree to other organisms. These ferments are low forms of life, animal or plant. The name ferment has been given also to certain unorganized bodies derived directly from living organisms, which bodies have special actions, thus the diastases have been called ferments; they have the power of converting starch to sugar. The name ferment has also been given to emulsin, to the digestive ferments, and to other bodies which have saponifying and other powers. Disease ferments which occur in wort have been alluded to before, they are real ferments. If a little brewing yeast be carefully washed to free it from sugary and gummy, and other matters, it is left clean and white; a very small portion of this placed under the microscope, will be found to consist of semi-transparent little cells, varying somewhat in size and shape, but all more or less globular or elliptical in form. The action of budding in the full-sized cells, and the growth and gradual detachment of others from these, can be distinctly seen. Watching the cells, circular spots called vacuoles appear; they are formed by the migration of the protoplasm of the cells towards the sides.* One or two prominences filled with protoplasm gradually rise, and these eventually separate from the parent cell as the bond of union lessens in diameter. Propagation proceeds very rapidly, and if the circumstances be favourable and the proper food supply be present, the propagation would go on continuously. It is usual to say that in an ordinary brewing any quantity of yeast will produce so many times (five to seven times) its own weight of yeast. These limits exist however because the food supply in the wort gets gradually smaller, and because other conditions, such as the formation of alcohol and acid, gradually weaken the propagating power. Theoretically, an infinitesimal amount of yeast could produce an infinite amount of the same, and the action would go on for ever, provided of course the usual conditions were favourable; one of these conditions being the constant renewal of food, and another the removal of the alcohol and other bodies formed. In ordinary fermen-

* P. Schützenberger, on Fermentation.

tations however, it can merely and generally be said that the newly-formed yeast is proportional in amount to the saccharine matter decomposed and so long as the sugar supply is sufficient. In estimating the yeast produce however, so many difficulties present themselves in consequence of the ever varying conditions under which the experiments are made, that no nearer results have been authenticated than that the yeast produced varies from 1½ to 3½ per cent. of the weight of the sugar decomposed. This production, as fermentation proceeds gets less proportionally; yeast seems to re-act upon itself or to come under different conditions, for some experiments prove that the yeast produced was as much as 15 per cent. of the weight of sugar decomposed, whilst the more plentiful the air supply the larger will be the amount of yeast produced for an equal quantity of sugar decomposed. The yeast so well-known to English brewers is only one variety of several forms, all of which produce alcoholic fermentation. In German brewing, a variety known as bottom yeast as distinct from the English surface yeast is generally employed. Surface yeast is formed more quickly and at higher temperatures than bottom yeast, and its tendency to rise is accelerated by the bubbles of carbonic acid gas which adhere to and surround the cells, and cause them to float. Though there is a general form recognised in one or the other variety, yet all phases of these and of the intermediate shapes are found in each. Yeast is a hardy plant, it can be dried and pulverised and yet remain alive; it can especially when dry be submitted to great extremes of temperature, though when moist it is killed at about 140° F., getting weaker as it approaches that temperature, but if the heat is not carried above 130° F., alcoholic fermentation will still proceed slowly, though at that temperature all disease ferments will be destroyed. Hence the benefits of Pasteurization as applied to beer; the closed bottles containing it are heated gradually to about 130° F. so that the process acts as a preservative. Yeast is comparatively active from 46° F. upwards, 77 to 86° F. being its most active temperature, but such are too high for healthy fermentation. It flourishes too when its most appropriate food is present, and the best food is such matter as is found in the healthiest cells, or such matters which by natural synthesis can produce this contained matter. Thus it has been found that the best food consists of water, mineral salts (especially phosphates) and nitrogenous matter derived from the albuminoids. Nitrogen in some form or other is thus one of the necessary food constituents, and careful experiments have shown that neither yeast nor other plant life gets this nitrogen from the air. Experiments have shown too that ammoniacal salts nourish yeast, and that yeast was able from these and sugar together to build *up its albuminous like contents. On the other hand it has been proved that albumen alone did not nourish yeast, nor is there any albumen in wort, nor strictly speaking any albuminoids after the wort has been boiled; besides, even if there were, their solution molecules are so large that they could not penetrate the membrane of the cell. But there are in wort, albuminous-like bodies called by brewers peptones; they are soluble even after the boiling; they are produced primarily along with the diastatic power, and they subsequently undergo a process of reduction and digestion before they are fit to nourish the yeast. These and other nitrogenous carburretted bodies allied to peptones,

* See P. Schützenberger, on Fermentation.

together with the mineral phosphates (especially of potash) are absolutely necessary for the yeast's nourishment. Yeast feeds upon these and the sugar, and it feeds apparently through the entire cell area, its porous membrane permitting this by an endosmotic action, whilst the matter which the yeast cannot assimilate is discharged by an exosmotic one. When no sugar is present yeast can still flourish in a mineral nitrogenous liquid, such as pure yeast water is, or in other such prepared liquids, provided there is plenty of air, but sugar favours the growth, though in a pure sugar solution alone yeast soon exhausts itself, for beyond the supply for the cellulose covering there is no nourishment for new cells. Yeast can, if sugar and the other food constituents are present, multiply without air, but the multiplication soon stops, though alcohol continues to be formed. It is doubtful in such a case whether the yeast gets its oxygen from the sugar or from the nitrogenous matter, though Pasteur once stated that it was from the former body. Yeast then, in ordinary cases, feeds upon these nitrogenous bodies, synthetises them to albuminous-like bodies, which again decompose readily. How the yeast cell whilst being nourished decomposes the sugar is not a matter to dogmatise upon; does the sugar actually pass into the cell's interior, where part is assimilated and the remainder discharged as alcohol and carbonic acid? or is the sugar so to speak digested by the active nitrogenous matter which always surrounds the yeast cell, and then passed into the cell? The cells at any rate discharge what they do not require, and this discharged matter which consists of saline and of soluble nitrogenous substances (chiefly of the latter which have an approximate constitution to the albuminoids) is chiefly remarkable for its high convertive power upon cane sugar. It transforms this to invert glucose sugar; in this respect it resembles the diastatic albuminoids which convert starch to maltose and dextrin, having therefore an equal right to be regarded as a ferment. This rapid inversion of the cane sugar to invert sugar is the preliminary step to its fermentation, for the glucose is a directly fermentable sugar. A rise in specific gravity accompanies this change, a strong cane sugar wort might gain several degrees by this means. Yeast may be collected and repeatedly washed and yet continue to exude this nitrogenous as well as the saline matter, although no food is meanwhile at hand and propagation has ceased. The washings gradually get weaker in inversive power, but this nitrogenous matter always accompanies the cells, indeed is formed at their expense. This excrementitious matter is always alkaline, though the cells themselves are acid, even when the alkalinity is neutralised by an acid it soon recovers itself as the discharge increases. Fermentation decomposes sugar in a way that no known chemical process can effect, although one is known which resembles the inversive power of the discharged nitrogenous matter. Dried yeast shows upon ultimate analysis a general resemblance to the albuminoids, though the two chief elements—nitrogen and carbon—have somewhat different percentages to what they have in the albuminoids, moreover these elements vary in quantity in different samples of yeast much more than they do in albuminoids. Again, there is more mineral matter in yeast than in albuminoids, and this mineral matter contains over 50 per cent. of phosphates. The general similarity between the two bodies has no doubt suggested the idea that the albuminoids are the food the yeast most delights in, in fact yeast has always been credited with feeding

directly upon the albuminous derivatives of grain. Leaving out the cellulose coatings of the cells, the analysis of the interior portion shows a composition very near to that of the albuminoids, sulphur however is absent from the yeast. These analyses naturally argue the existence of one or more albuminous substances in the cell's interior, though at the same time it is more than probable that these are built up by the cell itself and are not merely transfused into it from the outer wort. Divided into distinct bodies, dry yeast consists of cellulose, nitrogenous substances resembling albuminoids, and mineral matter, the latter amounting to from 5 to 8 per cent. of the dry yeast, and consisting mostly of phosphates of potash, lime and magnesia. The yeast contains also gummy, fatty and resinous bodies.

10.—PURIFICATION OF YEAST.

Yeast can be readily purified for the brewer's purpose by placing it in a pure solution of cane sugar which has been thoroughly boiled. A solution thus prepared of specific gravity about 1,040' and to which a few drops of carbolic acid solution have been added, or a few crystals of tartaric acid, is treated with an appropriate amount of yeast. The solution should be kept unexposed and eventually the newly-formed yeast collected from it. By this process the yeast is considerably weakened, but its recuperative power is great; other ferments, however, are almost entirely killed off, for although this treatment is unfavourable to the continuous growth of yeast, it is fatal to the other ferments. The newly-formed yeast can be used, and after an ordinary fermentation has been carried out a little of the produce from this fermentation should be examined under the microscope.

11.—ANTIFERMENTS AND PRESERVATIVES.

A high authority has said that all antiseptics are enemies to ferments, a fact equally important in medicine as in the especial subject now considered. All bodies too that cause the coagulation and precipitation of the food upon which the ferment lives must be regarded as inimical to it. A great many antiferments are known, they either precipitate or decompose the food upon which the ferments subsist, or they attack or resist the attacks of the ferments themselves. Such bodies are:—excess of any mineral or organic acid, excess of alkali, most metallic salts and hydrates, alcohol, phenol or carbolic acid, tannin, &c., &c. Most of these bodies by reason of their dangerous or poisonous qualities or on account of their expensiveness are unfitted for the brewer's purpose. To kill disease ferments and to act generally as antiseptics, many prescriptions are offered by advertisers, and they are suitable for cleaning vats and casks, for sprinkling floors, &c.; occasionally they are used for stopping fermentation when it is desirable to make an experiment upon wort at any particular stage. Well-known preparations for one or the other purpose are—solutions at various gravities of sulphurous acid and of bisulphite of lime; for general cleaning purposes chloride of lime, or a mixture of this with burnt lime. Salicylic acid is a valuable agent in arresting fermentation when it is desired to experiment

upon a sample of wort or to send a sample to a distance; five grains of the soda salt of this acid well mixed in a pint sample will effectively stop fermentation, whilst a less quantity will greatly reduce the action. Hops exercise a beneficial and agreeable preservative power against disease ferments; they are sometimes placed in beer casks, but a little hop extract, obtained by boiling water upon hops would probably be far more effective. Many other nostrums are used by brewers and publicans for brightening, colouring, frothing or imparting bitterness or tonic qualities to beer, but the alliance between some of these and adulteration is so close that they are best dealt with under that heading.

12.— CLEANSING.

This operation in most systems of fermentation is contemporaneous with it, often beginning with it but continuing after the beer has left what are recognised as fermenting vessels. Removal of yeast during fermentation is part of the cleansing process. For better effecting this, and for getting rid of suspended yeast and glutinous matter, and for running off the beer clear from sediment, the cleansing is carried out or at least completed in separate vessels. The simplest system in vogue is, to draw off the wort when its attenuation has approximately reached the desired point (though it is still well above that point), into large casks which have the capacity of several ordinary barrels. These casks are kept pretty well filled with the fermenting wort, and from time to time more wort is poured in at the bunghole. These casks are placed in a row upon a trough, the yeast rises through the bunghole and runs over into the trough below, and thence to the yeast store. Fermentation proceeds more slowly in these casks than in the original vats, because the temperature is reduced with the reduction of wort bulk, so these casks can form a refuge for too rapidly fermenting wort. The cleansing casks have plugged outlets a little above their bottoms, so that in drawing off into delivery casks the sedimentary matter is left behind.

Improvements upon this system which save much hand labour are extensively used. The casks placed in rows are filled from a trough or a reservoir, a main pipe from this leading by piping to each cask. The casks are often filled from the bottom, the wort in the reservoir or trough being always kept up to a certain level; thus keeping the casks pretty full, the yeast either falls over from the bung-hole down the sides of the casks into a trough, or as it rises through the bung-hole it flows up a pipe inserted therein; the pipe from its shape is called a swan-neck, and it conducts the yeast into a trough above or below the casks. Many modifications of this system exist, which save labour.

13.—FINING.

This operation is generally performed in the delivery casks, and to be effective should not be attempted till active fermentation has ceased, and cleansing has been carried out. Turbidity can to a certain extent be remedied by this process, but the turbidity may be of a permanent character, through faulty brewing, especially through bad mashing, so that the beer may contain suspended starch. Insufficient boiling may

cause turbidity through the existence of finely divided suspended albuminous matter, or disease ferments may be the cause of it. In these cases fining can only partially or temporarily effect a cure. Isinglass is a valuable fining agent, being a neutral and harmless substance. As it falls through the beer it carries with it the finely suspended matter which it encounters, for being of a sticky nature this adheres to it; the beer is thus left clear and bright. The isinglass before being used must be dissolved, and acidified liquor effects this; about two pounds will make a barrel of fining liquor. Sour beer which contains acetic and lactic acid has been used for dissolving the isinglass, but it has been pointed out that disease ferments, with their accompanying disagreeable taste and smell, are communicated to beer fined with this preparation. Acetic acid solution is sometimes used, but a solution of sulphurous acid is preferable, the isinglass does not so readily dissolve in the latter, but the strong acid qualities of the acetic solution render the beer tart. Sulphurous acid solution does not impart a disagreeable taste nor smell, whilst it is moreover an active disinfectant. Sometimes tartaric acid solution is used for the dissolving purpose, a few crystals of it being dissolved in water and the solution applied to the isinglass. From a pint to a quart of finings solution is added to a barrel of beer, it is well stirred up and then the cask is left lying still so that the sediment may settle.

14.—STORING AND DELIVERY FOR CONSUMPTION.

Though these would seem to be most simple matters, requiring no special teaching, and in fact nothing but common sense, yet in no other part of the brewing process is such carelessness shown towards the beer, nor such shameful treatment experienced by it, as in these its final stages. The brewer and the retailer are equally culpable in these respects. It is an every-day sight to see hogsheads of beer lying exposed in waggons, railway trucks and barges, to the broiling heat of the mid-day sun, their contents hissing and spitting as if to show their indignation at the ill-treatment they are receiving. To drenching rain or bitter frost it is perhaps next the lot of the beer to be exposed. It is not expected that brewers, nor railway nor shipping companies should construct vans or barges fitted with refrigerating or attemperating apparatus, as some sages have suggested they should do, but it is expected that beverages designed for the use of mankind should be treated with more consideration than is extended to coal or to pig-iron. No wonder the beer frets and fumes in its pent-up rage! In the matter of storing too in brewers' or publicans' stores and cellars; oftentimes these places are unfit to enter on account of their dirt and damp, their evil smells and their foul air. Store rooms should be dry and the beer therein neither exposed to strong winds nor to the hot sun, nor need they be hot-houses as their glass roofs sometimes make them. If fairly built, equable temperatures can be maintained throughout the year. The casks if mounted on channels escape the floor drainage and are easily moved. It is by no means necessary that store rooms should be in cellars or on basements, excellent store rooms at higher elevations exist at many breweries.

15.—BREWING OF PORTER AND STOUT.

London and Dublin are justly renowned for their excellence in these descriptions of beer. Burton however not satisfied with its acknowledged supremacy in ales, is entering the lists as a formidable rival in this kind of brewing. The broad distinction between the black beers and ales has always been in the former containing more nutritious matter and less alcohol than the latter. Taking samples of each, and of the same original gravity, this distinction generally obtains, but stouts are often brewed much stronger than ales, their original gravity averaging ten degrees or more above the average of ales. There is too, more acidity in stouts than in ales, and less tonic qualities, because less hops are used. Porters are weaker than stouts, but compared with ales the whole class of black beers is of a feeding rather than of a stimulating or *refreshing* character, and more suitable for cold weather and cold climates than ales. In order to effect the desired differences in the alcoholic and nutritive qualities, several of the details of the brewing process are modified. Soft water is usually employed for black beers; such water probably extracts more colouring matter than hard, or when it is extracted deepens its colour, especially so if alkaline salts are present. Stouts are generally said to contain more albuminous matter than ales, they probably do contain more nitrogenous matter derived from the albuminoids, but whether the soft water is the cause of this is a matter of doubt, though it is usual to trace the deficiency in nitrogenous matter in ales, first to the hard water employed dissolving less, and secondly to the precipitation of much of what is dissolved, the mineral salts giving temporary hardness to the water aiding this precipitation in the copper. Turbidity, which spoils the appearance of ales, is not so easily detected in stouts, whilst the finely suspended matter which may cause the turbidity helps to give mouth and fulness to stout. In stout brewing, the temperature of the mashing water is usually lower than for ales, the initial heat of the mash being at 145° F. or lower, this lower temperature aids the solution of albuminous matter. When the mash is once made however, its temperature is raised quickly, so that although the diastatic power was greater to begin with it is weakened, though not destroyed, by this elevation in temperature, the object being to prevent to a certain extent the conversion of the dextrin which is first formed from the starch, into maltose the final product. When once this higher mash temperature is reached the mashing can be prolonged, though if the same temperatures were used as in ale brewing, and it were desired still to produce dextrin rather than maltose, the *duration* of mashing would have to be *shortened.* A less quantity of hops is used than with ales—five to seven pounds per quarter being usual, or a larger amount of inferior hops is used. The fermentation is regulated too, so that attenuation will not proceed so far, and if the mashing has produced a more dextrinous wort than usual in ale mashing, this guidance of the attenuation is comparatively easy. Less yeast can effect the desired purpose, at least partially, only one or one-and-a-half pounds for a barrel sufficing. To produce the black colour a certain quantity of black or a larger one of brown malt is used. The proportional quantities of each kind—black, brown, amber or pale, in a quarter of malt used, vary so greatly, that it is difficult to mention any average quantites of each and yet to be gen-

erally exact. The quantity of each depends of course upon the colouring qualities of each kind. Thus, if the main bulk of the malt be pale, and the remainder all black, then this may be only 5 or as much as 15 to 20 per cent. of the whole; whilst if much amber malt be used, less black will be required, and if much brown malt, then less still of black is wanted. A small per centage, 5 more or less, of crystalline malt is often used to give flavour to the beer, and the total black, brown and crystalline malts may amount to 25 or 30 per cent. of the whole quantity used. Caramel is sometimes used to give colour, and sometimes it happens that a black beer is merely an ordinary ale coloured, this practice however is not porter and stout brewing.

16.—BREWING WITH SUGAR.

Sugar and syrup are used in large quantities, and by many brewers, for all descriptions of ales, porters and stouts, but like raw grain more as adjuncts to than as substitutes for malt. In 1847 sugar was first allowed to be used in brewing, and in 1874 all kinds of sugar and syrup were so allowed; under the head of statistics will be seen how this privilege has been used. The proportion used in any brewing varies greatly, ranging from 5 to 40 per cent. of the entire weight of mashing materials. Brewing with sugar requires far less labour than the ordinary malt brewing does, for the sugar is so easily and so quickly dissolved, either by condensed steam, by hot water, or by hot wort. Some have recommended that when cane sugar is used it should be introduced into the mash-tun with the other materials, in which case it would partly undergo conversion to a directly fermentable sugar, but if there were no other objection there would be the loss in draining to be considered. Often the sugar meets the malt wort in the underback; either it is placed in this vessel in the dry state or it is first dissolved; in either case the mixed wort is pumped into the copper as a whole. Frequently, however, the sugar, dry or in solution, is let direct into the copper; sometimes a platform or cage holding it is suspended in the boiling wort until the sugar is dissolved. Other brewers add the sugar at a later stage, namely, in the hop-back, where the boiling wort on its way to the cooler dissolves the sugar or mixes itself with the sugar solution. It is preferable that the malt and sugar worts should at least meet in the copper, for thorough boiling of the saccharine material has a beneficial effect, and is a safeguard against its impurities. Moreover, by being so boiled together the two kinds of wort get thoroughly mixed together and with the hop extract, so that a perfect and equable solution is obtained; but if the sugar is placed in the hop-back these advantages may not occur, or may only partially occur, and a sticky wort may pass through the coolers and over the refrigerator, rendering the cleaning of these vessels more difficult. If the sugar wort does not meet the other wort until the fermenting vessels are reached, a preliminary boiling of the sugar wort should certainly have taken place, and even then there will be the difficulty of mixing the two kinds of wort in the fermenting vessels to be considered.

Though many kinds and qualities of saccharine materials are used, they may be broadly divided into two classes; first, cane sugar and syrups, and second, glucose sugar and syrups. Of the first class it may

merely be said, that though several kinds are used they are all higher or lower qualities of cane sugar and of unrefined molasses and treacle. Of the second class many sorts are used, and under various names. Grape sugar, starch sugar, invert sugar, dextrose, and lævulose, all come rightly under the general name, glucose, and if they were pure would all have the same chemical composition, though they would differ in certain physical qualities. Some of these names are recognised in commerce as well as in science, but to some of these sugars other commercial names have been applied which indicate more or less correctly their source, and that is why so many varieties of saccharine and saccharum are advertised. They are mostly glucoses, or they contain a large percentage of glucose, together with more or less unconverted cane sugar, or unconverted dextrinous, gummy or starchy matter, as well as some burnt matter and some mineral salts obtained from the grain or formed during the manufacturing process. They all contain moisture also. These sugars are prepared chiefly in this country from raw or unrefined cane sugar, and also, after the husks have been removed, from rice, maize, and other cereals. These grain materials are treated with dilute solutions of mineral or of oxalic acid, and this, together with a high temperature and great steam pressure, rapidly converts the starch into dextrin and dextro-glucose or dextrose, whilst the cane sugar similarly treated is converted into invert sugar—a kind of glucose consisting of equal quantities of dextrose and lævulose. The excess of acid is neutralised by chalk, the precipitate is left, and the clear solution filtered if necessary through layers of charcoal. The glucose thus created contains in each molecule the elements of an extra molecule of water compared with the constitution of cane sugar; the lower sugars and the starches passing up to this stage are said to undergo conversion, though in the case of cane sugar passing up to invert sugar the process undergone is called inversion. Some of the glucose comes from Germany, and is sometimes obtained (by a similar process to the one described) from potatoes. All sugars, especially these prepared ones, are recommended by the vendors on the ground that when taking the place of malt or grain, less of the objectionable nitrogenous matter will be found in the wort, this matter being most liable to putrefaction and affording most nourishment to disease ferments, as well as having the most likelihood to cause turbidity. Using sugar certainly makes brewing far simpler, obviating all the care and anxiety attached to the regulation of mashing heats. As the sugars are meant to suit all classes of beer, they are produced either of a pale or of a dark colour, and they impart similar qualities to the beer. Fermentation, when the same quantity of yeast is used, is probably more slowly carried out when sugar is used than when malt alone is used, because there is less nitrogenous food for the cells, moreover the yeast is sooner exhausted for the same reason, whilst a smaller yeast crop is reaped, and it is said to be inferior in quality to malt-wort yeast. More yeast can easily be employed however, and provided there is sufficient of this, attenuation, if not as rapid as in malt-wort, can still be carried further, because there is less dextrinous matter in such a wort, this matter resisting fermentation more obstinately than sugar. Thus an alcoholic rather than a full-bodied beer is encouraged by the use of sugar. All the glucoses undergo direct fermentation; the cane sugar and its syrups are indirectly fermentable; the nitrogenous matter so

copiously exuded from the yeast cells rapidly inverts the cane sugar into invert-glucose, which latter is directly fermentable. What are the comparative virtues of beer brewed from malt and hops alone, and beer brewed partly from sugar, may be dismissed as a mere matter of taste, which, however, in spite of ancient ruling to the contrary, is a matter for very considerable disputation.

17.—BREWING WITH UNMALTED GRAIN.

Since the coming into operation of the Beer Act of 1880 this subject has greatly occupied the minds of brewers. Raw grain is now being used extensively as an adjunct to malt and sugar, its low price compared to that of malted barley being a great recommendation. The kinds of grain used are maize, rice and barley, and, to a less extent, wheat, rye, oats and sago. Success is rapidly developing the use of these, though many practical difficulties hampered the brewer at first, but experience has already taught the best methods of manipulation, the best proportions, and the most suitable temperatures. Sometimes the materials are used in the raw state, they are merely ground and mixed with the malt grist; at other times the grain undergoes a preliminary kiln-drying, this process driving off or burning up the volatile and other bodies which give to each kind of raw grain its characteristic rawness of taste and smell. The kiln-drying gives the grain instead a burnt and more agreeable flavour, renders the grain drier and more friable and brittle, thus making the crushing or grinding process more easy. The drying acts also as a purifier, killing off moulds and other low forms of life, it renders the starch cells less obstinate, gives a tendency to dextrin formation, modifies the albuminous matter, and is said to render this latter more diastatic. Kiln-drying evidently gives to grain something of the qualities of malt. Unmalted grain, however, is largely used in other forms and conditions than those just described. Many preparations are in the market, and they are designed for the brewer's direct use in the mash tun, without any preliminary treatment on his part. Some of these are fine meals or grists of kiln-dried grain. Maize meal is one of the commonest met with, the husk and germ *having been removed by suitable crushing and sifting, and as maize contains a large amount of albuminous matter—too large an amount for the brewer's purpose—this removal is very desirable. Other preparations are from grain which has been ground and then partly converted to dextrin and sugar. This has been done by treating the crushed grain (its husk being removed) with slightly acidulated water to soften it, which operation is performed by a steeping or by a rumbling process. After this, the material has been drained, washed, and finally dried on kilns at high temperatures. Raw grain material thus prepared, so that more or less of its starch is converted to dextrin and sugar, may almost be regarded as sugar, that is for the brewer's purpose. As, however, it still contains a certain amount of unconverted starch, it is always mashed with the whole, or with at least a part, of the malt, in order that diastatic action may then convert the remaining starch into dextrin and maltose, and the more starch there remains in

* In some of these grists, although the husk and germ are detached from the corn, they still remain mixed with the grist, and thus aid the draining in the mash tun.

these preparations, the greater is the care required in mashing, in fact the brewing process will closely resemble that which would be adopted when a mixture of malt and raw grain (the latter quite raw or merely dried) were employed. In mashing with such a mixture, the desired objects are to dissolve out or render soluble the starch, and then to convert it to dextrin and maltose, the latter phase being brought about by the malt grist or by the unboiled malt wort. One of the difficulties hitherto met with has been the setting of the starch before its conversion could be effected, this makes a consequent difficulty in draining. The diastatic power can hardly exercise itself upon the starch until the latter has been raised to a temperature at which the cells will burst, and a temperature considerably above 140° F. is required to effect this completely. But to add the malt grist or the malt wort to the starch infusion whilst this retains the temperature required to keep it from setting would be of little use, for the diastase would be destroyed, whilst to cool the infusion down to a favourable temperature for diastatic action involves the old difficulty of setting. To overcome both difficulties it has been found serviceable to thoroughly mix a portion of the malt grist with the grain grist, then to mash, and to raise the temperature gradually to one at which all starch cells are split, namely, to 185° F.; after this, in consequence of the partial conversion which takes place during the process, the mixed infusion can be cooled to the ordinary mashing temperature without danger of setting. The cooled mixture is then thoroughly mixed with the remaining malt grist, and the conversion is completed as in an ordinary mashing. Malt must be used to effect the conversion, because the albuminous matter of raw grain has very little diastatic action. Brewers can effect the first partial conversion in a separate vessel, and then let this mash into the mash tun to meet the remaining grist, or if there is no saccharifying vessel, both mashes can be made in the mash tun. Mr. T. W. Lovibond, one of the pioneers of this kind of brewing, has found something like the following details to be successful:—To each quarter of grain grist add about two barrels of water at a temperature of 140 to 160° F., so that the mash will be at about 120 to 130° F.; thoroughly stir all the time the mash is being made. Then to this mash add from 2½ to 10 per cent. of its weight of malt grist, and thoroughly incorporate it; this done, raise the temperature gradually to 185° F., or even to the boiling point, for five minutes; this can be done by letting in steam, mixing being continued all the time. Experience has taught what is the best rate under any particular conditions of raising the temperature (so many degrees per minute), also whether it may be advisable when the most favourable diastatic temperature is reached, and the starch cells are mostly burst (say 145 to 155° F.), to delay for a period the elevation in temperature. When the mixture has stood a little while at its final temperature, cool it by colder water to the proper, or a little above the proper, heat of ordinary mashing, that is to about the proper heat of the usual mashing water (155 to 160° F.), so that when the remaining malt grist is added the new initial mash may be about 150° F. Mix thoroughly the remaining malt with the infusion, and conduct the mashing now as an ordinary one. Mashing with raw grain thus takes longer time than an ordinary malt mashing, perhaps three-quarters of an hour longer. The brewer can produce a dextrinous or an alcoholic beer by regulating the temperature as in an ordinary mashing. If,

however, he uses a large quantity of raw grain proportionately to malt, or if in the first infusion he uses a large proportion of the total malt grist that he intends to use, there is more probability of producing a dextrinous beer, for in the first case the diastase has much raw material to act upon, whilst in the second case much of the diastase has only an opportunity of exercising a part of its power, for it is raised to the final temperature 185° F. too quickly to exercise its full power. Prepared raw grain meals are said to give better results and yield higher extracts than raw grain. Instead of following out the process as given above, the raw grain meal or grist can be raised very gradually to the boiling point, then cooled not below 160° F., then the malt grist is added; this method has given very good results. The quantity of raw grain used in a brew varies from the smallest up to 40 per cent. of the total materials. In consequence of the larger amount of starch in most of the raw grains than in malt, larger extracts are obtained than when malt only is used. The yeast is said to suffer partial starvation when large proportions of these highly starchy materials are used, still, beer brewed from raw grain may be made to resemble in appearance and in all prominent features any kind of beer brewed from malt alone.

18.—BREWING OF LAGER BEER.

To meet a growing demand for this class of beer, and to create a taste for it, beer more or less resembling the renowned lager has been of late imported from Germany. For ages the wines of the Peninsula have been manipulated to suit John Bull's real or supposed taste, at least this has been the reason given—whatever other reasons there may have been—why these wines come over so strongly fortified. Perhaps this has also been the case with lager beer; it came over more alcoholic and less dextrinous than real lager, in order, it is presumed, to comply with our insular proclivities. Dr. Graham, in singing the praises of lager, says, "We have no light, pleasant, conversation beer; no beer which one can drink freely of in summer to quench one's thirst." Lager supplies this want; it is approximately a non-intoxicating beer. But what say you, Burton, to this? There is no reason, provided the demand for it exists, why beer exactly resembling the lager should not be made in England, in fact, after several failures to establish such breweries, a large establishment has recently been opened at Tottenham, whence large quantities of genuine lager are sent out for consumption. Undoubtedly some English beers approach very closely the character of lager, though table beers, harvest beers, and others, which are light drinks suitable for summer, are regarded more as weak than as mild beers, as second brews made with less care than lager is known to require. Some attention, however, appears to have been paid to lager brewing by certain firms.

Lager, or store beer, is more dextrinous and less alcoholic than English beer; it is essentially a light-feeding rather than a stimulating beer; it is also less narcotic, less bitter, and less acid than our beer. Though these are the most apparent differences, yet it would be unfair to assume that all the distinctions can be thus summarised. The differences are fine, but perceptible enough to the taste and the smell, and are exemplified, too, in the after effect. The original gravity of

lager averages about 1050°, though samples considerably under and over this are met with. The mashing and the fermentation processes differ in lager brewing from the English methods, but it is in the long lagering or storing period that the beer acquires those mature qualities which distinguish it from English beer. The mashing process adopted differs in various parts of Germany, but the general object is to secure a highly dextrinous as distinct from a saccharine wort; the fermentation and the lagering processes in the various provinces are probably more similar. The malt is said to be highly dried on the kiln in order to promote dextrin formation and to destroy the active albuminoids. In mashing, sometimes a high initial temperature is used, and when the mash has stood for an hour, the wort, or part of it, is let off and boiled, then returned to the mash tun, where the diastatic action is now allowed to go on. Much of the albuminous matter is thus killed by the boiling, what remains in the mash tun becomes responsible for the completion of the conversion of the starch to dextrin and maltose. As the former, dextrin, is more easily formed, the brewer's object is generally effected. Another mashing system is, to commence with a small water supply, and leave the mash thus for an hour or more at a temperature of 120 to 130° F., albuminous matter is thus dissolved, but as the starch cells are hardly burst very little conversion takes place; the clear wort formed is let off and boiled, then returned to the mash tun at a suitable diastatic temperature; the wort and the grains are now thoroughly mixed. The small amount of albuminous matter which escaped solution in the first mash is left to convert as far as it can the whole of the starch, an hour being allowed for this. The dickmaisch or thick mash system is another. Mash is made with cold water, after some time a gradual rise in temperature is effected, thorough mixing being ensured. As the mash temperature approaches 100° F. a thick turbid liquor forms, and this is let off, or a part of it, with the goods into a copper, where it is boiled, constant stirring being necessary in this copper to prevent the goods from charring. The wort is then returned to the mash tun, thus raising the temperature of the whole mash; a thorough mixing is again made, and after a time, when the temperature is about 125° F., another portion of the wort and goods is let off and boiled as before. This is returned the second time to the mash tun, and thus the whole mash is raised to about 140° F. After a time yet another portion of the wort (by this time it is clearer than before) is let off, boiled, and returned the third time to the mash tun, where the best diastatic temperature will now prevail. Finally the clear wort is let off, and, as usual, the second mash or sparging ensues. After all this, the wort is boiled in the usual manner as in English breweries, but far less hops is used, say only 4 to 9 lbs. per quarter of malt. In all cases the wort is cooled by ice-cold water to about 38° F., it then passes to the fermenting vats. Dr. Graham computes that the saving in hops more than compensates for the expense of making or of buying ice. The hops are said to be gathered early in the season, and thus to be less narcotic. Much ice is used in keeping the wort down at a low temperature in the fermenting room, and afterwards in the store room, as much as three hundred weight per barrel is said to be thus consumed. Often, fermentation is conducted in underground cellars, a nearly constant temperature of about 40° F. being ensured. Yeast is added to the wort when the latter is at 39 to

42° F., bottom yeast being used, a little of it being first rendered active by aeration and by treatment with a little wort at a milder temperature. After twelve to twenty-four hours, fermentation slightly evinces itself, the little yeast that rises usually breaks down and falls. Ice-cold water, or ice itself, is used here and elsewhere to keep down the temperature. The first fermentation is complete in about twelve days, the beer is then casked and passed on to cellars, where it remains at a temperature barely above freezing point for three or four months. Even with this long time attenuation is not carried down far, the beer often having a gravity of 1012 to 1016°, which for an original gravity of 1050° is remarkably high. As the beer and the original wort always have a large ratio of dextrin to maltose the small attenuation is easily explained; the lager, too, always is rich in carbonic acid, for the slow but continuous fermentation is constantly renewing the gas.

19.—CONSTITUENTS OF WORT.

The constituents of wort vary in quality with the character of the brewing water, the quality of the brewing materials, and with the mode of treatment in the mash tun and in the copper. In quantity these constituents vary under the like conditions, but of course they are chiefly governed in this respect by the density of the wort, for the higher the density is, the more extractive matter the wort contains in any given volume. Speaking generally, it may be said that if an unfermented wort shows double the degrees of gravity over 1000 that another wort shows, then the former contains in any given volume of it, double the amount of extractive matter that the latter does. If two brewings were carried out under exactly similar conditions and with the same quality of materials, this statement would hold fairly well, though even in such a case a wort of, say 1080°, would not contain exactly double the extractive matter that one of 1040° would, but rather a little, though very little, over double. Tables have been prepared showing quantities of extractive matter in worts and in sugar and starch solutions, and though these tables may be used without involving much error, still they are only correct when worts or solutions are dealt with which have been prepared exactly as those were which originated the tables. Without direct estimation it is impossible to get at the total quantity of solid matter in an ordinary wort sample, but when specially prepared worts made from pure sugars are dealt with, then tables or factors may be safely used. A very usual and fairly correct factor is the number 2·6. It is very near exactness when the unfermented wort has a density between 1050 and 1060°, and the wort is made from carbohydrates alone. Ordinary wort, however, contains many other substances than carbohydrates, but as these carbohydrates form the largest proportion of the wort's solid constituents, the factor may be used with approximate correctness, and in a formula such as the following:—Say the wort's gravity is 1060°, then $(1060-1000) \times 2{\cdot}6 =$ number of grains of solid matter in 1000 grains' measure of wort at 60° F., and thence the solids in any other volume can be arrived at. The factor applies equally well when a brewer's saccharometer is used, say such an instrument showed in a wort 20 pounds per barrel, then the solids in a barrel at 60° F. would be approx-

imately 20 × 2·6 pounds. The factor 2·6 is derived from the fact that 2·6 grains, say of pure dry sugar, when dissolved in pure water and the bulk made up to 1000 grains' measure at 60° F., would give a solution of 1001° gravity.

The quantity of each kind of material in a wort can only be ascertained by analysis. The chief constituents next to the water itself are the saccharine and starchy bodies, these form over 90 per cent. of the solids. According to the kind of sugar used, the wort will contain either a glucose sugar or cane sugar, whilst from the malt or grain used the wort will derive its maltose sugar, its dextrin and any starch which may be present, though part of the dextrin and starch may also be derived from glucose sugar which has not been thoroughly converted. The nitrogenous constituents of wort are also derived from the malt and grain. Besides all these there are the various substances derived from the hops. Finally, there is the mineral matter which is derived, first, from the brewing water—this water may contain sulphates, carbonates, and chlorides of the alkaline-earthy and alkaline metals; secondly, from the grain, which, besides the above salts, may contain silicates and phosphates; and thirdly, from the hops, which contain much the same kinds of salts as the grain. The sugar used will also introduce a further small quantity of salts.

20.—CONSTITUENTS OF BEER.

Beer contains a much larger variety of constituents than wort, for besides the bodies proper to the wort, or rather the residuum of these, it contains the products of fermentation. These have been dwelt upon in detail in subheading (c) *Principles of the Fermentation Process.* The quantities of the fermentation products are governed by the beer's original gravity, and by the extent to which, and temperature at which, fermentation has been carried on. Some beers have a density of as much as 1040°, whilst others have a density but little above that of water. As much as 70 or 80 degrees of apparent attenuation may have been experienced by a beer, but the actual loss of gravity would be less than this attenuation or apparent loss, because in the latter the spirit is always present when taking the lowest gravity, so that the real gravity due to the remaining unfermented solid matter is masked by as much as 12 or 13 degrees. The actual loss of gravity is that due to the decomposition, alteration, and precipitation of fermentable and other solid matter, and this loss can only be ascertained when all the spirit which has formed has been removed, and the sample's bulk has then been made up to its original one by adding distilled water. The formation of alcohol and of the other fermentation products is fairly proportioned to this actual loss of gravity, so that if two worts had original gravities of 1040° and 1080° respectively, and if they both showed when their spirit was removed and their bulks made up as indicated a density of 1020°, one would have lost 20, the other 60 degrees of actual attenuation, and the fermentation products would be approximately three times as great in the second case as in the first. The converse holds good too, for if three times the amount of alcohol and of the other products have been formed in one fermentation and in similar volumes as compared to another fermentation, then three times

the amount of fermentable matter has been decomposed or altered in the one case as compared to the other, and the loss in the actual gravity of each will have been proportional.

Stouts and lager beer contain (supposing like original gravities to have existed) larger amounts of solid matter than ales, and this is chiefly due to the fact that more dextrin exists in stout and lager worts when they leave the mash tun than exists in the ale wort, or as it is usually expressed, the ratio of dextrin to maltose is higher in stout and lager worts than in ale wort. Fermentation down to any fixed point is consequently more difficult to effect in the former classes of beer than when, as in the case of ale, the wort is comparatively richer in sugar.

In worts prepared by ordinary mashings, the ratio of dextrin to maltose varies from 1 to 5, to 1 to 3, though under other conditions other ratios may exist. After fermentation these ratios are considerably altered, the dextrin always gains proportionally, so that the new ratio of dextrin to maltose varies from ·7 to 1, to 14 to 1, the longer the beer is kept the more the dextrin gains in this respect. Summarising the constituents of beer, it may be said that the solids vary usually from 3½ to 9½ per cent. of the beer's weight, the average percentage for ales being about 5½, of which about 5 consists of organic solids (sugar, dextrin, lower carbohydrates, nitrogenous matter, hop extract, &c.), and the remainder of mineral solids (chlorides, sulphates and phosphates). In stouts the average solids is 7½ per cent. organic, and ½, mineral solids. Alcohol varies in beer from 2¾ to 8½ per cent. by weight, or, in other words, the beer varies from 6·1 to 18·4 per cent. in proof spirit, the average being 5½ per cent. alcohol or 12 per cent. of proof spirit, so that beer contains far less alcohol than wine, the same remark applying also to the acid, the total acidity of beer varying from ·1 to ·3 per cent., the former being only a little below the average for ales. The acidity increases with age. A gallon of beer at 1015° gravity would weigh 10·15 lbs., and if this contained ·4 per cent. of mineral matter there would be scarcely 300 grains of it in the gallon, and if the organic solids were 7 per cent., about ¾ lb. of this would exist in a gallon.

21.—INQUIRY INTO THE COMPARATIVE COSTS AND VALUES OF BREWING MATERIALS.

The brewer has a ready way of estimating the cost of brewing materials by the amount of wort, at a standard gravity that a fixed weight of them will produce. Thus, a quarter of malt costs, say 42s. 6d., and it yields, say 4 barrels of an original gravity 1,059°—this expressed in brewers' terminology—would be one barrel of 85 pounds gravity*; so that one pound of gravity costs $\frac{42s.\ 6d.}{85}$=6d. Expert brewers may get a yield 85 or 88 to 89 pounds per quarter of malt, that is about 8 per cent. over the standard yield of 4 barrels at 1,057° gravity, or as brewers would say, of 1 barrel of 82.08 pounds; many small brewers do not get so much as the standard yield. When porter or stout is brewed the yield is much less—say, only 70 to 75 pounds per standard quarter

* Relation of "pounds per barrel" to degrees of gravity, is fully explained on page 50 and 51 of author's book on *Original Gravity*.

(336 lbs.); for the brown, black, and crystalline malts, though yielding flavour and colour, yield less solid extract. By adopting the standard brewing bushel of 42 lbs., and therefore of 336 lbs. per quarter, comparisons of the costs of materials can easily be made; the amount of wort produced is found, its gravity taken, the quantity of materials used being also known. It can be then calculated how much wort one quarter would have yielded; and when this yield is expressed—in pounds, per barrel, per quarter—direct comparisons can be made. The following calculation was suggested by a detailed account, showing costs, published in the Brewers' Journal at the end of 1881:—Used in brewing, 3 quarters of malt and 4 cwt. of maize meal; or in other words, 24 bushels of malt and $\frac{448}{42}=10\frac{2}{3}$ bushels of maize meal. The quantity of wort produced was found, and on calculation the yield was found to be 89 pounds per barrel for each quarter. As $4\frac{1}{3}$ quarters of grain were used, this total yield must have been $89 \times 4\frac{1}{3}=385\frac{2}{3}$ pounds. The cost of the material was, 3 quarters of malt at 42s. 6d.=£6 7s. 6d., and 4 cwt. meal at 9s. 6d.=38s.—total cost, £8 5s. 6d; hence the cost of a pound per barrel was $\frac{\text{£8 5s. 6d.}}{385\frac{2}{3}}=5\frac{1}{4}$d. nearly. An ordinary barrel of beer then of 22 pounds original gravity, that is of 1061°, would cost less, by nearly 1s. 6d., than if made entirely from malt. Hence, when about 30 per cent. of raw grain was used something like 1s. 6d. on a barrel of ordinary beer was saved, so that the attraction to use raw grain must be very strong. In this case the malt was known to yield 85 pounds per barrel per quarter, hence the 3 quarters would have yielded 255 gravity pounds; the total yield was $385\frac{2}{3}$ pounds of gravity; so that the maize meal contributed $130\frac{2}{3}$ gravity pounds, and as $1\frac{1}{3}$ standard quarters of this were used, the pounds per barrel per quarter yielded by this, must have been $\frac{130\frac{2}{3}}{1\frac{1}{3}}=98$ pounds, whilst the malt yielded only 85. The cost of a gravity pound yielded by the meal was $\frac{38\text{s.},}{130\frac{2}{3}}$ or as the cost of 1 cwt. was 9s. 6d. and of a quarter 28s. 6d., and the yield per quarter was 98 pounds, the cost of a gravity pound was again $\frac{\text{28s. 6d.}}{98}=3\frac{1}{2}$ very nearly. This can be compared favourably, with the malt's cost of 6d. per gravity pound. Far better yields than this have been obtained, amounting to 115 or 120 pounds per barrel, bringing the cost of a gravity pound to less than 3d. Rice too, at 8s. per cwt. or 24s. per quarter, can yield 102 pounds per barrel per quarter, costing thus 3d. per gravity pound, or less. A specially-prepared grain mixture from rice and maize, costing 36s. per quarter, will yield about 96 pounds per barrel, the cost being thus $4\frac{1}{2}$d. per gravity pound. This is a higher cost than that of some of the other raw grain preparations, or raw materials; but in this case the use of the prepared mixture is facilitated, for it can be used in the ordinary mashing without any risk, and without any extra labour on the brewer's part. The saccharines and the sugars cost more per gravity pound, but the fact of their being so easily dissolved into wort recommends them in spite of this. Brewers using any kind of materials can thus reckon the cost per pound per barrel, and thence of the cost of a barrel at any original gravity.

A useful and simple way in which brewers can calculate the percentage extract actually obtained from the corn materials used, is by dividing the "pounds per barrel" per quarter by 1.26. Say a quarter of malt yielded 86 "pounds per barrel," then the percentage extractive matter derived from the malt, is $\frac{86}{1.26}=68.2$ Fairly accurate results are obtained by the use of this rule; the results are not likely in any case to vary more than 1 or 2 per cent. from the truth. The divisor 1.26 is thus derived, $\frac{2.66 \times 100}{336}=1.26$; the derivation of the factor 2.66 being itself explained under heading 19, "Constituents of Wort"; whilst the number 100 represents 100 pounds of malt or corn, and the number 336 the weight of a standard quarter of the same.

It has been said that good malt, with skilful management, will often yield 88 to 89 pounds per barrel; this malt will have yielded about 70 per cent. of its substance to the water, or at least this percentage will remain dissolved after the wort has been boiled. Of the remaining 30 per cent., 23 is made up of the dry grains and insoluble matter, the remaining part being moisture which existed in the malt. This is very good work. Prepared meals yield higher extracts, because in the first place the germs and husks have been removed, and because these materials contain a higher percentage than malt of soluble carbohydrates (starch and sugar). It is not easy, however, to arrange the various cereals malted and unmalted in any fixed scale of yields, because there are so many varieties and qualities of each kind; some are dry, others contain much moisture; some again in each variety contain different percentages of starch. Taking it that rice contains most starch, then wheat, maize and barley follow in order, so that the extracts will be proportional. The price of each has however to be considered; first, the price say of a standard brewing quarter (336 lbs.), and then, knowing the yield per quarter, the cost of a gravity pound. Taking average prices and average yields, the same order of merit as in the starch series exists: thus, in the four following kinds of materials, and weight for weight, rice costs the least, then maize, then barley, and highest of all, malt. Taking next average yields from equal weights, and comparing with costs of equal weights, it is found that with maize the cost of a gravity pound is 2d. to 3d.; with rice and oats, 3d. to 4d.; with barley, 4d. to 5d.; and with malt, 6d.

The correctness of the assumption, that a quarter of malt should yield not less than 4 barrels of wort at 1057° original gravity, is so palpable, that no time need be spent in defending it.

22.—INQUIRY INTO SUGAR EQUIVALENTS.

In fixing the sugar and syrup equivalents, it was necessary to know the equivalent yields,—what weight of these saccharines would yield as much extract as a bushel or quarter of malt,—for it is right that they should be taxed according to their wort-yielding capacities. It is known that from 65 to 70 per cent. of the substance of malt will be found in the wort after boiling; say the average extracted from malt is 67 per cent., over 90 per cent. of this will be carbohydrates. Now a standard bushel weighs 42 lbs., and 67 per cent. of this is about 28 lbs.

If 28 lbs. of dry and pure sugar be taken it would totally dissolve, so that it can be seen that under these conditions 28 lbs. of it would yield as much wort as a standard brewing bushel of malt. Of course such a close comparison cannot always hold; malt may yield more than 67 per cent. of its weight—or the sugar—as is most likely, may be impure may contain some moisture, and consequently will yield less wort. Thus the various sugars, saccharines, and saccharums advertised, yield from 75 to 80 pounds per barrel for each 2 cwts. (the equivalent of 336 lbs. malt), they thus fall short of the revenue standard which requires 4 barrels at 1057°, *or 82.08 pounds per barrel from each 2 cwts. A materials charge however is not likely to occur in consequence of this, for the saccharine materials form only the lesser proportion of the whole mash, and moreover the 4 per cent. which is deducted in a materials charge greatly rectifies any previous over charge. Syrups, which contain more or less water, are allowed to be used at the rate of 34 to 41 lbs. for each 28 lbs. of sugar. Thus, 34 lbs. of cane-sugar syrup (when a gallon of it does not exceed 14 lbs.) are only reckoned as 28 lbs. of sugar, so that only $\frac{28}{34}$ or 82 per cent. of the syrup is charged. A solution of pure cane sugar, weighing 14 lbs. per gallon, has a specific gravity of 1400, and a solution of this density contains from 75 to 78 per cent. of pure dry cane sugar, and contains of course a higher percentage of sugar if its ordinary state of dryness be considered; so that it is fair to charge only 82 per cent. of the syrup's weight as sugar. Again, 41 lbs. of glucose syrup (when a gallon of it does not exceed 13 lbs. 2 ozs.) is reckoned as only 28 lbs. of sugar, so that only $\frac{28}{41}$ or 68 per cent. of the syrup is charged. A syrup of this weight would have a specific gravity of 1312.5, and a solution of pure glucose of this density would contain from 62 to 64 per cent. of pure dry glucose, and of course more glucose in its ordinary state of dryness.

Corn or grain which has been prepared by removing the husks, and has then been so treated that part of its starch is converted to dextrin and starch, is fairly charged as sugar, provided a fixed weight of it yields as much wort as the same weight of sugar would. Comparing glucose with cane sugar it may be said generally that, weight for weight, the former is a dearer material than the latter, but this of course must depend upon their relative states of purity. Ordinary glucose often contains from 9 to 15 per cent. of moisture, which must lessen its value. Again, pure glucose compared with pure cane sugar will, weight for weight, yield less wort, because it contains more of the elements of water in each molecule of its composition. Before cane sugar wort ferments it has been shown to undergo inversion, the wort is thereby raised in gravity, though the rise is unnoticed when the cane sugar forms only 20 to 30 per cent. of the brewing materials; but an entire cane sugar wort would by inversion gain 2 to 3 degrees of gravity or more, according to the solution's density. A cane sugar wort of 1057° is thus as valuable as a glucose wort of 1059° to 1060°, or 100 parts of dry cane sugar, are equivalent in wort-yielding power to 105 of dry glucose.

* Three months after the above was written the Inland Revenue made an important concession to brewers, whereby 32 lbs. of certain sugars, instead of 28, were to be taken as equivalent to a bushel of malt.

23.—PROGRESS OF INVENTIONS AND DISCOVERIES CONNECTED WITH BREWING.

Though on taking a general view it may be said that the prominent features of both the malting and the brewing arts are in the main similar to what they have been for ages, yet it is impossible when examining these arts in detail to find any points but what have been modified or improved as wider experience and more accurate knowledge have been gained. The pre-eminence enjoyed by the staple materials, malted barley and hops, seems as likely as ever to be maintained, in spite of legislation, which from 1847 upwards has progressively allowed the use of sugar, of hop substitutes, of syrups, and of corn of any kind. The old materials have not been supplanted, simply because they have been found to be the best, but the methods and means of using them have undergone great improvement, and with the best economical results.

If any art can be said to be a primitive one, then that of malting is so, though the practice of it throughout long ages has no doubt introduced changes. In spite, too, of the staunch conservative spirit which maltsters, as well as brewers, are credited with, it cannot fairly be urged that maltsters as a class are behind the time. If malting is naturally a simple process, it is needless to try to complicate it; there is plenty of scope for improvement both in the malting and the brewing processes, without the introduction of changes which are merely changes. The restrictions under the malt tax were asserted by some to hinder improvements, but this cannot be proved. Practicable improvements are always being adopted, but suggestions which would tend to convert malthouses into chemical laboratories, or into carefully-regulated germinating conservatories, are not practicable ones. A complete change in the present system of malting, as recommended by some, is not likely to take place—a gradual perfection of the present system seems far more desirable. Many recent improvements may be noticed: the implements used by the workmen are improved ones, the method of turning by means of a light machine running over the floor saves much hand labour, so too does the use of hoists, pulleys, tramways, &c. in loading or unloading the kiln. Improvements in the make of the kiln floors, whereby, amongst other advantages, an equal distribution of furnace heat is ensured, is important—double floors in some cases favour this equal distribution of heat. Improvements in the kiln roofs which remove the inconvenience resulting from the dropping of condensed steam, and which secure good ventilation, are worthy of notice. The thermometer is now always used on the kiln, and the proper depth of malt on the kiln is better looked after. Improved machines for sifting the malt and for removing rootlets are in use. New malthouses are better constructed than of old, steam-power and machinery are introduced and adapted; the proportional capacities and areas of cisterns, floors, and kilns are looked to, as is also the better storing of the malt. The theory as well as the practice of malting is better understood.

The brewing art is a far more elaborate one than that of malting, and permits of a much wider range to the inventive faculties. Neither floor, nor roof, nor anything between, has escaped notice. The introduction of steam must have rendered much possible which previously was undreamt of; it has been utilised in the working of water and wort

pumps, in the feeding and the exhausting of certain vessels, in the grinding and the crushing of corn, in elevating casks, sacks, &c., in the chain ladders for removing the grains from the mash tun, and in the revolving stirrers for mash tuns, coppers, &c. Naked steam too has been found useful for heating purposes, for dissolving sugar, and for cleaning vessels. Of late years, a brewers' exhibition has aided inventors, chemists, architects, and engineers in making known their labours. The mere catalogue of recent improvements is a long one. The best position for each vessel and room has been studied, so too has the best and fittest materials for vessels, floors, roofs, &c. Then there are the fittings of mash tuns, the constructing of mashing and sparging apparatus, false bottoms, and attemperating apparatus. In fermenting vessels—attemperating, skimming and rousing apparatus have been introduced. Hop and yeast presses have also been adopted. The splendid refrigerators in use are wonderful improvements on the old systems of cooling, though the present perfection was only gradually acquired; some of these refrigerators can cool to any temperature, above that of the cooling water, as much as or more than 100 barrels per hour. Another important introduction to modern brewing is the saccharometer. It was probably a hundred years ago when this instrument was first known to brewers, and it was found to be a good guide, though its exact indications were not properly understood. The instrument has been from time to time improved and corrected; taken with the thermometer and with the known bulk quantity of the wort, it allowed the brewer to perform many useful calculations. It showed "pounds per barrel." In 1822, Bate's Saccharometer showing degrees of gravity was introduced, this being also an improvement on older gravity saccharometers, which had the various facings and weights still met with in old instruments. This improved saccharometer became of great service to the brewer and to the Revenue, and it gave much closer indications than the usual brewers' saccharometer. The brewers' saccharometer is, however, for many purposes equally serviceable, though in ignorant hands it always leads to a misconception of what "pounds per barrel" are: they are taken to mean actual pounds weight of extract in a barrel, instead of the extra pounds weight that a barrel of wort or of beer has over the weight of a barrel of pure water.

The saccharometer paved the way for another most important invention, namely, that of finding original gravities. This process was not invented all at once, several failures taught the lessons, which acquired, eventually brought success. To a few officers of the Inland Revenue Department belongs the honour of finally completing this work. The commission which investigated the whole of this subject a few years later consisted of three eminent scientific men of the time. They were appointed to their work in 1852, and they performed their work thoroughly well, their report being of great service to the science of brewing. Beyond making a few alterations in the tables employed, they could suggest no improvement in the method which had been employed by the Inland Revenue Department during the five years previous. The future importance of the invention was perhaps hardly appreciated by its inventors; it was at that time used only for ascertaining the amount of drawback payable on the exportation of beer; now it affords the ultimate standard in fixing the duty on all beer produced, the saccharometer which suggested the original gravity method afford-

ing itself the ordinary or primary standard in assessing the duty on unfermented wort. Information was acquired by the investigating commission which will enable an experimentalist to use appropriate and correct tables, no matter from what materials wort is produced; but the great merit of the original gravity process is not so much in its scientific aspect (though this is important) as in its universal practicability combined with its exactness.

The introduction of new brewing materials marks another phase of advancement in the brewing art. The abolition of legal restrictions has gradually set the mash tun free. Many special preparations of the new brewing materials have relieved the brewer from much anxiety. To those enterprising brewers who have first essayed themselves, and have then taught their colleagues how to employ their newly-acquired liberty, the best thanks of the brewing trade are due; Mr. T. W. Lovibond is one of those who have thus made raw grain brewing a success.

But there is another class of persons to whom brewers owe a debt of gratitude. The successful practical man often reaps his own speedy reward, but the claims of another—no less deserving class—are more tardily recognised. Years of hard and patient work may be spent in the laboratory, or in the study, with apparently little to show for them. The results become at length known, and in course of time come to be appreciated, not merely by the student, but by those who can practically utilise these results of close research. The author of the "Art of Brewing" performed a great service for his fellow brewers, when in connection with another person, he translated Pasteur's Studies on Fermentation. It is a pleasure to find this book so highly appreciated by the class whom most it concerns. The microscope followed as a matter of course, and is now used for many useful purposes in breweries. In connection with other brewing subjects, analysts and brewers have learnt to appreciate the patient and skilful labours of Messrs. Brown & Heron, and of Mr. O'Sullivan, of Burton-on-Trent. It is fortunate that these gentlemen are in positions to make practical use of their own scientific studies. The author of the "Manual of Brewing," Mr. Hooper, deserves the grateful recognition of brewers for his precise information, the result of well-trained and well-directed labour. Dr. Graham, of University College, London, and other men in other towns, have done much in rightly directing the brewing art, for it is through the labours of students that the scientific knowledge concerning brewing is becoming so complete. Correct analytical processes are being gradually effected, and in this branch of progress much credit is due to the analysts of the Somerset House Laboratory. It has occasionally been urged by critics, for their own interested purposes, that this body of men have contributed little or nothing to original scientific research. To disprove such statements is beside the purpose of this paper, but it is indisputable that besides other important services that these men have performed, not the least is the perfecting and the adapting of the suggestions of others, and the establishing thereby of analytical processes which have both a general and a special suitableness. Large experience has enabled these men to create processes which can be used under any variety of probable circumstances out of general data, which otherwise have but a limited usefulness. Many published analytical processes are of value only to such as can adopt the general process to the special circumstances of the case under con-

sideration, and to such as can make the appropriate allowances and corrections. Experience is the chief quality that permits a man to do this, and it is because this has been wanting that not a few otherwise admirable public analysts have involved themselves in difficulties. These remarks specially apply to the analysis of beer and wort, and to the detection in these liquids of the various sugars. Generally, analytical knowledge as applied to brewing has developed greatly of late years. The copper oxide reducing powers of the glucoses and of maltose have been investigated, a standard has been fixed, and the proportional powers adjusted to this. So, too, with the specific rotatory powers of the carbohydrates. Through the progressive stages of lævulose, invert sugar, dextrose, cane sugar, maltose, dextrin and starch, this power has been shown to increase. The distinctions between the various kinds of dextrin—the achroo and the erythro—have been studied, as have also the formation of the starch cell, its constituents cellulose and granulose, the diastatic power of the malt albuminoids, and the whole subject of starch transformations. Correct tables and formulæ for finding the specific gravity of the carbohydrates, and for the calculation of their percentages in solutions, have been published. The polariscope has become a valuable adjunct to analytical chemistry, for by means of this and by other acids, the starchy and saccharine values of brewing materials can be calculated. Impurities in these materials, as well as in hops, yeast and brewing water, are readily detected by special processes.

24.—ADULTERATION.

From 1816 to 1880 brewers were under the restrictions of the 56 Geo. 3, cap. 58, which act forbade the use of molasses, honey, &c., and many special adulterants, as well as any other substitutes for malt. Until 1862 substitutes for hops were also disallowed, but the restrictions ceased that year with the abolition of the hop duty. So far as sugar was concerned the act of 1847 allowed its use, whilst that of 1874 extended the privilege to the use of any saccharine material. In 1875 the Food and Drugs' act came into force, and this is now the only one under which adulteration of beer by the brewer can be dealt with, except in so far as the use of sugar without entry may be regarded as adulteration. There can be no doubt that beer is now brewed better than ever it was, whilst any adulteration which might take place so as to bring the brewer under the operation of the Food and Drugs' Act would be very difficult, if not impossible, to discover by any system of excise survey. Various nostrums are in use for giving permanent frothiness or heading, or for giving brightness or tone to beer, but the detection of these requires most careful chemical analysis; moreover, in order to convict, it would have to be proved that these mixtures, as also those bitter extracts used as hop substitutes, render "the article"—beer—"injurious to health;" or else to prove that the purchaser was "prejudiced" when he bought the beer. It is noteworthy that many of the largest firms indignantly deny the use of any kind of hop substitute. So far as brewers are concerned, beer may generally be said to escape adulteration, though it may fairly be urged that if all the hop substitutes are as harmless, nay rather, as beneficial, as they are adver-

tised to be, then why should their use, with such laudable objects, be effected so quietly? The same tolerance however cannot be extended to the retailers, and it is well that these persons and dealers still come under the chief conditions of the act of 1816. This act confers upon the Excise Department powers which are very difficult to exercise successfully and still more loathsome, nor can the act of 1875 (Food and Drugs) be adapted with anything like success against the dishonest retailer. Culpable neglect, however, is a charge which can be more generally urged against the retailer than the crime of adulteration can; the neglect consists in careless storing, and in omitting to have the delivery pipes connected with the bar tap, clean and wholesome. Under the pretext however of brightening, of frothing, or of preserving the beer, the disreputable publican in the low neighbourhoods of towns makes use of preparations which impart false potency, which mask bad quality, and which have the effect of creating thirst instead of letting the beer quench it, and which act as opiates and strong intoxicants. Excise supervision would be and is incompetent to prevent this kind of adulteration, for the adulterants though powerful are minute enough in quantity to permit of ready concealment. At the risk of being considered "grandmotherly," I believe that the state or the local authorities should put down adulteration whenever it is practicable to do so, but the adulteration of the kind referred to, though extensively pursued, would be impossible to eradicate, it is in fact beneath notice. The easiest remedy is to warn the customers, and if this warning be neglected (as it often would be), the customers must even take the consequences.

25.—STATISTICAL.

(A) *Consumption of Beer.*

Official reports show that in the year ended 31st March, 1882, duty was charged upon 27,870,526 standard barrels, of which 182,964 were brewed by those private brewers who pay duty. Of the total charged, 499,353 were exported on drawback, leaving 27,371,173 for home consumption. Of this number, 24,379,038 barrels were accounted for in England, 978,032 in Scotland, and 2,014,103 in Ireland. The quantity charged in the year ended 31st March, 1882, exceeded by over 500,000 barrels the quantity charged in the year ended six months previously, namely, 30th September, 1881. Taking the population of the United Kingdom in the middle of 1881 as 34,788,814, and omitting the quantity of beer imported, and the unknown quantity brewed by those private brewers who pay no duty, it appears that the average consumption per head of population in the United Kingdom was about $\frac{3}{4}$ of a barrel, and by making a similar calculation it can be shown that in England the average beer consumption was about 1 barrel, in Scotland nearly $\frac{1}{3}$ of a barrel, and in Ireland about $\frac{1}{2}$ a barrel. These are approximate averages, but it must be borne in mind that large quantities of the beer charged in Scotland and Ireland are consumed in England, though as a set off to this there is much beer brewed in England which finds its way to Scotland and Ireland. In deducing temperance statistics from the above ones, it must be remembered that the consumption of whiskey per head of population excels largely in Scotland over Ireland, and in Ireland over England.

(B) *Number of Brewers.*

In the year ended 30th September, 1881, there were, including transferees (amounting to about 1300), 17,110 brewers for sale, and in the next year ended 30th September, 1882, there were, including about 1000 transferees, 16,609 brewers for sale. The great bulk of these are comparatively small brewers, brewing under 1000 barrels annually, the number of these being 14,948 and 14,499 for the two years, and if the brewers brewing under 10,000 barrels annually be computed, it will be found that in both years these brewers comprised about 97 per cent. of the total number. Only three brewers brewed over 800,000 barrels in the first of the two years, and only two did so in the latter year, though the third brewer nearly reached the number. The largest brewer in the United Kingdom brewed over 1,000,000 barrels in the first year, and nearly 1,200,000 in the latter, and he paid in the latter year duty amounting to £374,483 10s. Over 98 per cent. of the brewers for sale carry on their business in England. Besides the brewers for sale there are over 110,000 private brewers, and of these nearly 98 per cent. are in England, those in Ireland may be counted on the fingers.

(C) *Quantities of Materials used.*

In the year ended 30th September, 1881, there were used by brewers for sale 51,901,240 bushels of malt and corn, and also 128,712,977 pounds of sugar and syrup equivalents. In the next year ended 30th September, 1882, the quantities were 53,097,099 bushels of malt and corn, and also 129,047,817 pounds of sugar and syrup equivalents. As the bushels are standard brewing ones, weighing 42 pounds each, it seems that in both years the weight of sugar used was about 5½ per cent. of the total brewing materials.

(D) *Revenue from Brewing.*

In the year ended 30th September, 1881, the amount of brewing licences and beer duty charged was £8,498,044 2s. 5d. For the next year ended 30th September, 1882, the annexed particulars have been published:—

		Amount of Licence Duty paid.			Beer Duty charged.		
Brewers for sale	...	£15,671	0	0	£8,652,734	14	8¾
Other brewers	...	32,306	2	0	49,541	12	8
Total	...	£47,977	2	0	£8,702,276	7	4¾

The average revenue derived from the malt tax, malt licences, sugar used in brewing, and brewing licences, during the six years ended 31st March respectively and preceding the abolition of the malt tax, &c., amounted to £8,672,000. If all the malt used by those private brewers who pay no duty were charged at the rate paid by brewers for sale, the revenue under the Beer Act would have considerably exceeded that derived under the malt tax.

(E) *Exports and Imports.*

Compared with the colossal proportions of the brewing trade, the exports and imports of beer are very small. In the year ended 31st March 1882, 499,353 standard barrels were exported on drawback, the

duty repaid being £156,048. This was a considerable increase over the preceding year, still the export trade may be described as stationary. The quantity exported is about $\frac{1}{56}$ of that produced. The largest shipments go to Australia, next in order is British India, then South Africa and the United States. In Australia especially, and in the other colonies, as well as in British India, the brewing of beer is increasing, so that the export trade to these places will have greater competition than hitherto. The import trade in beer is also very small; in the year ended 31st December, 1881, the imported quantity was 12,013 barrels, this being about $\frac{1}{36}$ of the exports, but this trade shows signs of increasing.

26.—LEGISLATION AND TAXATION.

Putting aside for the moment the question of taxation, it may be said that one of the chief results of recent brewing legislation has been to confer more and more liberty upon the trade. The repeal of the beer duty in 1830 acted beneficially towards the consumer, and was a blow to the brewing monopoly. In 1847, sugar was allowed to be used in brewing, its use however was very slowly developed at first, for in 1866 the amount used did not reach 10,000,000 lbs., but now (1883) the amount used is about thirteen times as much, being nearly 130,000,000 lbs. In 1862, with the abolition of the hop duty, brewers were allowed to use any hop substitutes, though, financially, they were not gainers to the full extent of the repealed hop duty, for they were charged instead with a tax of 3d. per barrel, or rather of 1s. per quarter of malt or of sugar equivalent used. In 1874, the freedom in regard to the use of sugar was extended to all kinds and qualities of it and to syrups. The year 1880 saw the abolition of the old Adulteration Act of 1816 (so far as it applied to brewers), and the throwing open to brewers of almost a free choice of brewing materials.

The great value of, and the precise incidence of the beer tax, could never be so clearly demonstrated as they can be at present, for beyond a small annual licence, there is nothing, so far as taxation is concerned, besides the beer duty levied on his actual or his computed produce, which interferes with the brewer's calculations as to cost. The tax is practically on the finished article, there are no cumulative taxes falling on the brewer because of interest or of profit upon the taxes on raw materials. Certainly the beer retailer pays a tax which acts as an indirect tax upon the consumer, but this has nothing to do with the brewer's calculations as to the cost of his beer. For long periods taxes on malt, on hops, and on beer, ran side by side, besides various licence duties on brewers, maltsters, malt roasters, &c. The malt tax especially was subject to much variation; the beer duty was changed from time to time; and the hop duty seems to have been temporarily extinct just before and at the commencement of the 18th century. This latter duty has varied since that time from 1d. to about 2½d. per lb., being at 1½d. per lb. when it was repealed in 1862. The malt tax has fluctuated very much, having been as a rule higher in England than in Scotland

or Ireland, and also as a rule lower in Ireland than elsewhere. For the last 60 years, however, the same rates have prevailed in the three parts of the United Kingdom, exceptions being made for inferior barley in Scotland and Ireland. The duty has varied during the nearly 200 years through which it may be traced, from about 6d. to 4s. 6d. per bushel, being highest at times of war. It was at 2s. 7d. and five per cent. per bushel when it was abolished in 1880. The beer duty was for a long time a considerable source of revenue; it can be easily traced to the time of the Commonwealth, and it continued until 1830. Frequently, both before and since that date, the brewer must have paid a far higher tax than he does now, especially so during the periods between 1819 and 1830, and between 1854 and 1857. Adam Smith, a hundred years ago, recommended the repeal of the beer tax, and the making of an addition to the malt tax instead. He showed that in his time, the duties alone on beer and malt (without the maltster's profit on the tax) cost the London porter brewer an amount equal to between 26s. and 30s. on the produce of a quarter of malt, whilst the country brewer was taxed to about 23s. to 26s. per quarter's yield. The brewer at that time too was handicapped, as Adam Smith shows, by the rich and middle classes being able to brew their own beer duty free on payment of a small capitation fee for malting free. Now-a-days, so many complaints are made on behalf of brewers, with or without their consent, that one almost believes that the beer duty falls ultimately upon them instead of upon the consumers. It can be shown that the largest and the best brewers pay a higher tax than they did prior to 1880, but it can be shown too that the smallest brewers pay less than they did. In comparing the present tax with the former total tax on beer, the fact that maltsters, malt roasters and others paid licence duty must not be overlooked, nor must the maltster's profit or interest on the tax of 21s. 8d. per quarter that they paid be forgotten, for all these affected the brewer's previous total payment.

The mode of assessment of the present tax is admirable, whether the object be to tax the beer according to the brewing or wort value of the materials used, or according to the alcoholic yielding power of the wort. The alternative tax on the quantity of materials used is a wise provision against fraud and carelessness. To have taxed the beer upon its actual alcoholic value would have created various anomalies when regarding the amount of materials used in the production of the beer, moreover such a scheme would be far less simple than the present. To have taxed the beer fairly according to a materials' estimate alone, would have required many distinctions to be recognised between the various qualities, but such distinctions would have rendered the scheme impracticable. To have levied the tax in accordance with an attenuation charge, would have involved the same difficulties as the alcoholic proposal, and would, moreover, have introduced other inherent inaccuracies, which alone would render such a scheme very unfair.

Turning to another subject, it has often been alleged that the rapid falling off in the number of brewers is because of increased taxation since 1880, and that therefore the abolition of the malt tax in that year has proved a calamity to the brewing trade. It may be stated once again, however, that the class of brewers (the very smallest ones) that is so rapidly diminishing pays now a less tax than formerly. These brewers pay duty on a materials' charge, and at the rate of 22s. 9d. per

quarter of 336 lbs., they being assessed at 144 gallons on each such quarter, and from this number first 4 then 6 per cent. is deducted, so that only 131 gallons are left to be charged at 6s. 3d. per 36 gallons. Formerly they paid through the maltster at the least 21s. 8d. per quarter of only 324 lbs., besides 1s. per quarter for brewing licence, and further they paid the interest or profit of the maltster on his net payment of 21s. 8d.

Official reports show that since 1838 the number of brewers for sale in the United Kingdom has been rapidly diminishing, and this long before the present beer duty was dreamt of by brewers. From 1830 to 1838 the number rapidly increased, for there can be no doubt that although at that time the consumer suffered from the heavy tax and from the monopoly, yet brewers did so also; the legislation of 1830 however encouraged many persons to join the trade. But the falling off soon commenced, has continued and doubtless will continue, for large capitals will always swallow up smaller ones, and big brewers will tie the smaller brewing victuallers and others to themselves. In speaking of the change made in 1880, the Board of Inland Revenue state that the transfer of the malt tax to a beer tax had long been delayed upon economical grounds, chiefly because of the large number of small breweries and the consequent expense of collecting the tax, but as in 1880 the number of small brewers was so small compared to the number at Her Majesty's Accession, namely, 22,278 compared to 49,200, the transfer from the malt tax could then be recommended.

The following facts are recommended to the notice of such as complain that brewers are too heavily taxed:—The beer tax since 1880 till now (December, 1883) has been at the rate of about 2d. per gallon of ordinary beer, nor would the rate, after allowance for waste has been made, amount even on the very strongest beer (say of original gravity 1110°) to over 4d. per gallon. A fairly strong ale would not contain more than about 12 per cent. of proof spirit, and if the tax on such ale be reckoned at 2¼d. per gallon (it would scarcely ever exceed this), then it appears that if an alcoholic scale were adopted to suit the present tax on beer, the alcohol would only be taxed at the rate of $2\frac{1}{4}\text{d.} \times \frac{100}{12} =$ nearly 1s. 9d. per gallon of proof spirit. Proof spirit existing in whiskey made in the United Kingdom, is taxed at 10s. per gallon, and besides this tax, there are the distillers' and the spirit dealers' licences to pay. Foreign spirits too are taxed at the rate of 10s. 4d. per proof gallon, so that spirit, as produced by the brewer and by the distiller respectively, pays a tax in the low ratio of 1 to 6. If comparison be made by means of the materials used in the respective trades the same favorable condition holds; thus, a quarter of barley malt used by a distiller will yield 18 gallons of proof spirit, the duty thereon being £9, whereas a quarter of barley malt used in brewing will produce 4 or 4½ standard barrels of beer, and the tax on this (allowance for waste being deducted,) would barely exceed, in any case, 25s.—that is to say, this tax compared with the distillers' is as 1 to 7. With the sugar materials a similar comparison may be made.

27.—THEORY AND PRACTICE.

The union of the qualities represented by these words is necessary for the advancement of any art, and the practical brewer is fortunate who possesses the requisite amount of theoretical knowledge. Equally unfortunate is he who knowing something of the theory disdains to make himself acquainted with the practical details of his trade. The important art of brewing is rapidly developing, and in studying deeply the many questions of cause and effect connected with so large and flourishing an industry, it is almost impossible for one person to devote himself to this kind of research, requiring as it does long and special training, and to be at the same time in a position where he can apply practically the results of his study. Hence it is, that connected with this and every other art, a class of men exist who may be identified as theorists as opposed to men who are engaged in carrying out the ordinary routine work. Gradually, the results of the students' labour are understood and adopted by practical men; still it must often happen, that for a time at least, the doctrines deduced from scientific research are neglected, if not actually combatted with, by practical men; whilst no doubt, at other times, it happens that theories are advanced which viewed practically are absurd, whilst in other cases certain practical processes may be demonstrated as theoretically faulty or imperfect, but the remedy suggested (if any) is entirely inapplicable from economical or other reasons. A certain amount of antagonism may thus in one way or another be created, and this is intensified on the one hand by theorists, who, without any sufficient amount of study, and with no responsibility, but perhaps with interested motives, advance dogmas which are incompletely supported, or which flavour more or less of quackery; whilst on the other hand it is intensified by pompous practical men, who believe in their own infallibility, and who obstinately turn a deaf ear to any new suggestions or improvements. Even the eminent author of *Studies on Fermentation* alludes in his modest manner to the difficulty he had in demonstrating to some English brewers that they were injuring their produce for want of sufficient care over their yeast. Pasteur's labours, however, are an example of how the student can help the practical man; his great success was reaped in consequence of his many splendid qualities, among others, that of studying the partial successes and the failures of others. Men in their time, perhaps, equally eminent in one or the other branch of science, have studied the same question that Pasteur devoted himself to, and though their names are forgotten by the world at large, their memory is revered by the students of the particular studies they undertook. The purpose of this paragraph is to show that whilst the brewer is perfectly justified in repelling all mere theoretical suggestions which flavour of quackery, or of inexperience, or which are totally opposed to common sense, yet he ought to place due emphasis on the importance of original, scientific study, and he should be ready to avail himself of the discoveries and inventions accruing from such study.

28.—CONCLUSION.

I wish to express my grateful thanks to those gentlemen connected with the brewing trade, both in London and the country, who have given me so much practical information in reference to the brewing processes. Such courtesy shown towards an official has afforded an instance of the proper relations which should exist between the tax-payer and the individual whose duty it is to levy the tax, who, whilst his first duty must always be to protect the revenue, can at the same time perform that duty thoroughly without making his presence vexatious to the trader.